THE

SCOTTISH GEOGRAPHICAL MAGAZINE

THE ROYAL SCOTTISH GEOGRAPHICAL SOCIETY
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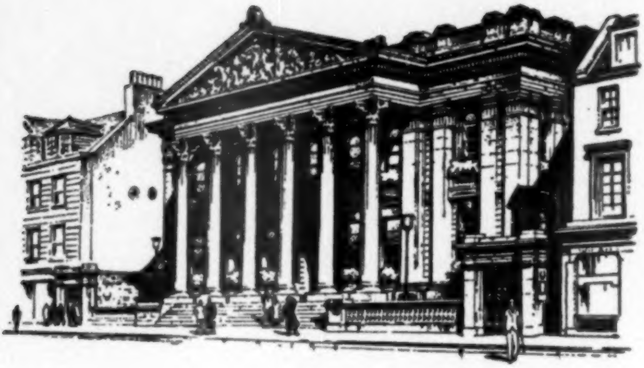

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166	Fodor, Eugene	Austria, 1958; Germany, 1958, Spain and Portugal, 1958.
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LOCATIONAL AND STRUCTURAL ASPECTS OF INDUSTRY IN EDINBURGH

C. J. Robertson

THE industrial belt of Edinburgh extends from the port of Leith southward to Queen's Park and through the centre of the city as far west as Sighthill. (Fig. 1). The axis of this industrial crescent runs along the Water of Leith, where a number of the earlier industrial establishments used the primitive waterpower, and through the old town. Brewing was being carried out at Holyrood Abbey in the twelfth century and breweries later extended along the line of wells from Abbeymount westward along the Holyrood Road in the depression between Calton Hill and Arthur's Seat. The first printers in Scotland were established in Edinburgh in 1507 and before the end of the sixteenth century paper was being made at Dalry, while by 1770 six other small paper mills are known to have been established on the Water of Leith as well as two on smaller streams [1]. Some of these were conversions of already existing meal mills. Paper-making, however, as its scale increased, became centred on the valley of the North Esk, beyond the bounds of even present-day Edinburgh, and the small mills were abandoned. By the end of the seventeenth century a foundry had been established, as well as glass-works, powder and textile factories [2]. By the early nineteenth century ship-repairing and biscuit-making had also become established industries. Steam was substituted for water as the source of energy on some of the old sites and the industrial axis was reinforced by the building of the Union Canal in 1822 and by the development of the railways in the forties.

The Edinburgh area lacked the raw material basis for the heavy industrial development characteristic of the earlier growth of production and transportation in Britain. Some expansion of engineering took place after the railways were built and shortly after the middle of the nineteenth century the traditional food and drink processing industries of Edinburgh were supplemented by such a forerunner of the new industrial revolution as rubber. Greater mechanisation and transportation

facilities and increasing population encouraged and were encouraged by larger volume of production. The density of resident population increased from the late seventies in the vicinity of the railways. Industry pushed eastward into Portobello, where brick works were established, and later an outlier of the main belt was developed at Craigmillar, where brewery extension took place from 1890. In the twentieth century minor concentrations have developed on the foreshore at Granton in the north and still more recently at Sighthill in the west (See Fig. 1). While the later development of road transportation gave flexibility in industrial siting, both in supply of raw materials and in distribution of the product,

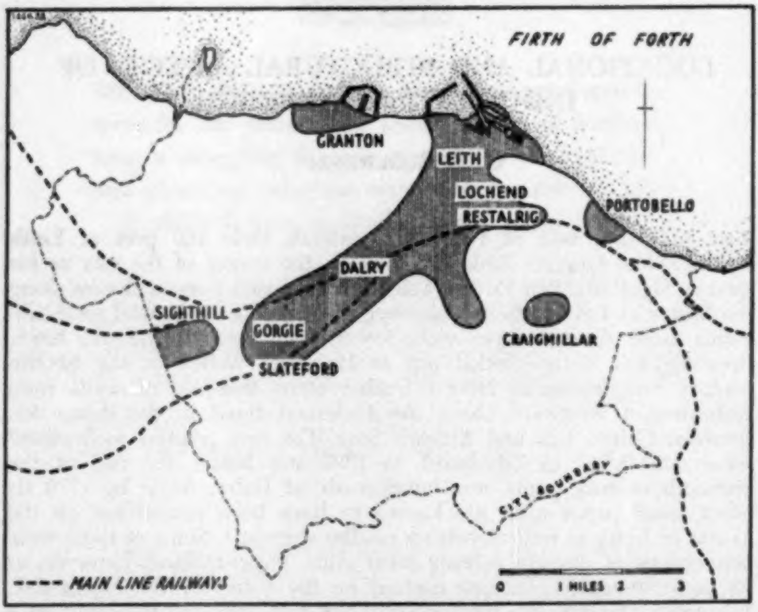

Fig. 1 Edinburgh showing area (shaded) within which most factories are situated.

the original industrial axial zone has proved to possess considerable inertia. New firms have frequently taken over already occupied sites while old firms have rebuilt or equipped on the same site to avoid the expense of taking over a new site from the foundations. This tendency has been encouraged by the existence of basic services in older areas and by the ease of travel to work to these areas from the new housing estates. In 1920-30 the main axial zone was still filling up westward in Gorgie. On the other hand the older sections of the central zone had become highly congested both in housing and traffic and this, together with the rising urban rentals in the better areas and the extension of electricity supply, accelerated the centrifugal movement of industry.

One of the new areas, the Sighthill Industrial Estate, may be regarded as a further westward expansion of main the axial zone.

Gradual adoption of new sites with changing energy and transportation facilities is illustrated by the baking industry. Haulage was a difficult problem and the sites of the earlier bakeries were near the flour mills on the Water of Leith (for example, Canonmills and Bonnington) where primitive water power and local grain were used. With the use of imported grain Leith itself had an increased advantage. After a transitional dependence on the railways, the greater flexibility made possible by road transportation led to siting in the then newer housing areas (for example, Restalrig).

Industry in Edinburgh has grown not only by extension of older firms both in the older sections of the industrial belt and its outliers but by agglomeration of new firms attracted by the building up of public services and of a reservoir of skill and experience. Examples from the older industries are the migration of one brewery from Ednam in Roxburghshire to Craigmillar in 1890 and of a paper-bag and carton firm from Loanhead to Edinburgh in the eighteen-seventies. More striking was the addition of several rubber firms soon after the initial success of the pioneer firm founded in 1857; this was followed by the establishment of three firms, respectively in 1861, 1866 and 1877, mainly for the production of proofing but also for hard rubber articles. The increase in number of biscuit manufacturers is another instance, one of the largest, a Canadian firm, having come to Edinburgh after having found an initial footing in Aberdeen.

INDUSTRIAL STRUCTURE AND INDICES OF SPECIALISATION

At the 1951 Census of Population Edinburgh had exactly 1.0 per cent of the occupied population of Great Britain (against 2.3 per cent

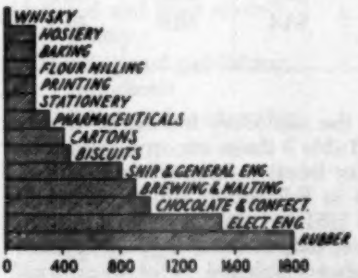

Fig. 2a Edinburgh: size of plant in which most workers are occupied; mode based on numbers of workers.

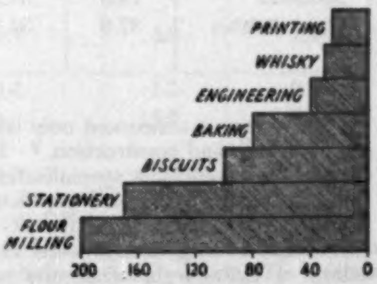

Fig. 2b Edinburgh: most frequent size of plant; mode based on number of firms.

in Glasgow). As might be expected of the seat of Scottish administration and law, it has a relatively high proportion of its occupied population in the service industries (which include medicine, education, law and religion as well as transportation and communications, distributive trades, finance and public administration).

The critical differentiating factor is seen to be the proportions of female employment. This raises the total percentages of employment in the towns above the averages in Scotland. In this respect Edinburgh occupies a middle place between the higher total and female employment ratios of Dundee and Glasgow and the low ratios of Aberdeen. (See Tables 1 and 2).

Table 1. Percentages of occupied population in main industrial groups.

	Edinburgh	Glasgow	Great Britain
Primary	2	—	9
Secondary	40	51	46
Tertiary	58	49	45

Table 2. Percentages of : (A) population 15 years and over; (B) gainfully occupied females to total gainfully occupied population; (C) total population occupied.

	A			B	C
	Males	Females	Both Sexes		
Edinburgh	87.0	36.8	59.1	36.3	47.1
Glasgow	89.9	38.9	62.6	35.0	47.2
Aberdeen	87.4	33.2	57.2	33.5	43.6
Dundee	88.6	45.2	64.3	39.8	49.2
Scotland	74.6	37.2	57.1	30.3	43.1
Great Britian	87.9	34.5	58.4	30.6	45.3

This paper is concerned only with the secondary industries, that is, manufactures and construction. [3] In Table 3 these are arranged according to their indices of specialisation (or location factors); their proportions of the total occupied population in Edinburgh and the numbers engaged in each industry in the city in 1951 are also given. The location factor is of more general interest since it indicates the regional specialisation of Edinburgh, while the number employed is of more local interest. The figures refer to the 1951 Census of Population and include all secondary industries with location factor over unity. The use of the location factor or location coefficient has been developed by P. Sargant Florence. The same figures are obtained by calculating the index of specialisation as used in a recent study by J. A. Sporck. [4]

The high figure for wholesale bottling is connected with the large whisky blending industry, grain whisky (from unmalted cereals and malted barley) being blended with Highland malt whiskies and bottled in Leith. Leith has an old-established wine trade and the blenders

commonly began as wine merchants and most still deal in wine. They combined the blending and bottling of whisky about 1900 to meet the requirements in the first place of the London market. Danish lager is also imported and bottled in Leith. Edinburgh obtains bottles from factories in Portobello and Alloa and also through the port of Leith.

Table 3. Secondary industries in Edinburgh 1951.

	Location factor or index of specialisation	Numbers engaged (000)	Percentage of total occupied
Wholesale bottling	9.9	1.5	0.7
Biscuits	6.7	2.7	1.2
Brewing and malting	4.3	3.7	1.7
Rubber	4.2	4.4	2.0
Manufactures of paper and board	3.1	1.4	0.6
Grain-milling	3.1	1.2	0.5
Printing and publishing, other than periodicals	2.5	6.2	2.8
Drink, other than brewing and malting	2.3	0.9	0.4
Cocoa, chocolate and sugar confectionery	2.2	1.6	0.7
Cardboard boxes, cartons and fibreboard packing-cases	2.0	0.9	0.4
Marine engineering	1.8	0.9	0.4
Bread and flour confectionery	1.7	3.0	1.4
Printing and publishing, periodicals	1.6	1.5	0.7
Building and contracting	1.1	15.8	7.2
Electrical goods other than machinery	1.1	1.6	0.7

The proportion of employment in building and contracting is rather higher than Edinburgh's own population would suggest, the location quotient being 1.14 against Glasgow's 0.97, a difference probably connected with the function of the city as an administrative centre for projects in other parts of Scotland.

EDINBURGH AS PART OF THE MID-LOWLAND INDUSTRIAL AND TRANSPORTATION NEXUS

Examination of the sources of raw materials and of the destinations

of finished products of Edinburgh industries leads to the conclusion that within an area such as the Scottish Mid-lowland, with a well-developed transportation nexus, there may be a wide choice of locations with ready accessibility to fuel, water and suitable labour. This is especially true for industries collecting their raw materials and distributing their products over an area far wider than the immediate sphere of influence of Edinburgh. The circumstances in which the rubber industry was located in Edinburgh provide an illustration. The demand for rubber products in Britain was increasing rapidly. In the first place the choice of a Scottish location was due to the accident that the Hancock patent, filed in England in 1843 and used by Charles Macintosh and Company there, had not been filed simultaneously in Scotland, where, until 1852, it was necessary to apply for separate patent rights. Goodyear had succeeded in anticipating Hancock in Scotland in 1844 and an American company seeking to manufacture rubber boots and overshoes in Britain and using the Goodyear patent was therefore able to open a factory in Scotland in 1856. It had been the original intention to locate the factory in Glasgow but the immediate availability of premises in Edinburgh at the critical time determined the eventual choice. The Edinburgh factory had readily available water, coal and female labour for the manufacture of rubber footwear, which became a leading branch, securing a substantial proportion of the British market. The manufacture of industrial belting was soon added and, after the invention of the detachable pneumatic tyre in 1890 and its application a decade later to the automobile, tyres became a major branch of production at Castle Mills. The absorption of a neighbouring vulcanite factory (founded in 1861) in 1910 added hard rubber articles to this firm's activities. Today raw materials are collected from a wide compass – raw rubber from London, synthetic rubber and sulphur from the United States, rayon from Wales and Liverpool, cotton and nylon from Lancashire, jute and flax from Dundee, carbon black from Chester, oxides and carbonates from Durham, pigments from Wilton and Manchester, china clay from Cornwall, wire for tyre beading from various firms in England, while packaging is largely supplied by Edinburgh firms. Since 1947 about three-quarters of the goods are carried by road. But a number of the factors that had permitted this degree of indifference in location were destined to weaken and make drastic readjustments necessary after World War II.

There may be great flexibility in taking supplies from different sources according not only to mere physical availability but to prices and business connections, which may mean central buying to supply factories in different parts of the country. Thus, while Edinburgh is itself an important grain-milling centre, the movement of flour from its two largest mills is, notably in the case of the Scottish Wholesale Cooperative Society's mill, partly to tied bakeries throughout Scotland, while on the other hand one of the largest bakery firms in Edinburgh brings in flour by road from Liverpool, the headquarters of this combine, which has a central buying policy. Much flour also comes from Glasgow, Scotland's principal milling centre, and smaller quantities from Dalkeith, Kirkcaldy and Carlisle. Again, given the possibilities of regular and speedy service, transportation differentials are outweighed by other

considerations. In the brewing industry too transportation, now mainly by road, is a relatively small factor in costs despite the fact that one of the two largest brewers has a market extending throughout Britain and the other into the North of England, while exports, now only a small part of the total though for one of the smaller firms still the greater part of its sales, go mostly through Glasgow. Similarly most of the whisky for export goes by road to Glasgow or Liverpool for shipment and whisky for export dominates the trade, about 75 per cent of the whisky blended in Leith being exported.

The presence of considerable engineering in Edinburgh is in part also accounted for by the dispersable character of the industry within a much larger area of good accessibility. It is an industry using components drawn from many sources, with varied products and many markets and calling from time to time for changing emphasis within the same firm to secure rapid adaptation to technical changes. There are also however branches that are market-bound to a particular industrial complex since they produce highly specialised machinery for a particular industry. Such a case in Edinburgh is the construction of paper-making machinery, in the first place for the paper mills of the Esk valley and neighbouring areas. Industrial linkages of this last type are however exceptional and only partial in the Edinburgh area. The stationery industry in Edinburgh is one of the few examples of close interdependence with local industries on either side, its main materials in the paper industry and its main market in the administrative and educational institutions of the capital. There appear to be practically no Edinburgh industries using smaller local firms to produce components. Larger firms think in terms of their own national organisation rather than of merely regional links. Nor do local firms rely on Edinburgh for supplies, there being ample competition from outside the area through travellers and catalogues, while good communications and transportation make available a wider field of supply.

THE PORT OF LEITH

A special instance of the transportation factor is the influence of the port of Leith. Some of the traditional 'seaport industries' are in this northern sector of Edinburgh's industrial crescent. Grain-milling is the most important, depending mainly on imported wheat, and this is the leading import of Leith, three-quarters of the total going to two large mills, one of which handles 7,200 sacks (900 tons) of flour a week or 60 sacks (7.5 tons) an hour. Of the total flour used in Edinburgh itself 70 per cent is from Canadian wheat, which is hard and so gives the light porous bread that is preferred. Continuous automatic working requires steady channeling of supplies, which means good handling and storage facilities. The port authority is alive to this and is extending the elevator capacity at the docks to 71,000 tons. The elevator and mill capacity of Edinburgh make direct shipment of wheat to Leith without break of bulk economic. On the other hand, for the miscellaneous raw materials other than flour Edinburgh bakeries obtain much, if not most, of their supplies by road through sundriesmen from Glasgow whole-

salers. This is true also for the chocolate and sugar confectionery industry but a fair amount of cacao beans and fats, for example, is brought in directly through Leith. The home-grown barley, mostly local, that the brewers use, provided it can compete with overseas supplies, also comes in by road. While the feed compounders get much of their grain locally, additional supplies come in through Leith and from time to time through the Clyde, whose oilseed mills have also, thanks to the large-scale operations of the port, squeezed out the former oilseed-crushing industry of Leith. The compounding industry, using a wide range of raw materials – including also fish-meal from Aberdeen – involving little loss of weight in processing, is market-oriented and the greatly increased popularity of compound as against straight feeds means that local markets are proportionately greater. But the industry probably remains at the port of Leith only by inertia, the six firms having a 'residual' location.

On the other hand the fertiliser industry, like grain-milling, retains its port location by the sheer bulk of a single raw material – in this case phosphate rock from North Africa and Nauru. The largest fertiliser factory in Scotland is coming into operation. This is a plant for making ammonia-based fertiliser. Leith has a central position on the east coast from which Scotland's principal agricultural areas are readily accessible and general trends in agriculture make for increasing demand for standardised compound fertilisers.

While there are occasional shipments of rubber to Leith, the brokerage and warehousing facilities of London, together with its port accommodation and return cargoes for vessels in the Far Eastern trade, make London the principal port of entry for the rubber used in the Edinburgh industry as well as for supplies of tea. Of the wine brought into Edinburgh most comes through Glasgow, only 10 per cent through Leith, to which there are not suitable sailings for such a part cargo.

With the exception of wheat and fertilisers then, there does not appear to be a high degree of transportation-oriented location at the port of Leith, which is in fact unable to handle the larger ships that bring mixed cargoes and has neither sufficient local market in South-eastern Scotland nor the return cargoes to attract such ships and the fast and regular services that they could provide.

Edinburgh thus depends mainly on Glasgow and to a less extent on Liverpool and London for its supplies of raw materials. In one important respect its dependence on Glasgow goes farther; part of its bread supplies comes from Glasgow. Although baking has a location quotient well over unity and higher than all Scotland, bread production lags behind demand in Edinburgh and in South-eastern Scotland. One large Glasgow bakery (connected with one of the Edinburgh flour-milling concerns) sends bread daily to a depot in Saughton, for delivery in Edinburgh to the two smaller retailing firms in the same concern. Edinburgh distributes bread as far as Eyemouth, Jedburgh and Hawick. Industrially Edinburgh is thus to a considerable extent dependent on Glasgow, a number of industries using raw materials brought in by road from the west to produce goods for South-eastern Scotland.

MECHANISATION, AMALGAMATION AND SPECIALISATION

As regards internal structure Edinburgh industries have shared in the trend toward larger units. The largest industrial unit in Edinburgh is in the rubber industry, in which at the time of the 1951 Census of Population 3,315 persons, 75 per cent of the then total in the industry in Edinburgh, were occupied in one plant. Founded in 1857, this company had extended its manufacture from rubber boots and light shoes not only to tyres, hose and belting but to hot-water bottles, sheeting and car accessories, golf-balls and flooring. Between 1910 and 1957 all other Edinburgh rubber companies except one were absorbed or liquidated. Competition in this industry is severe. Since 1948 the original specialisation in footwear has met with competition from Hong Kong. In tyres the Edinburgh firm has to meet strong competition from three other British companies in the home market. The automobile industry is mainly in the Midlands and South of England while the replacement market is dominated by the fact that half the vehicles are in the London area. The industry in Scotland, though it has a considerable and regular market in maintaining tyres for large local users such as bus companies, has thus a peripheral location and so is more sensitive in times of intensive competition. Greater mechanisation, relocation and specialisation within a larger financial structure have been the conditions of survival. The footwear department in the Edinburgh plant was mechanised and subsequently, in 1951, the production of light footwear and flooring was moved to Heathhall, Dumfries – like the original establishment in Edinburgh, to a disused factory – and the remainder of the footwear department in 1955. United States holdings in the company were increased between 1947 and 1956. The overseas interests were transferred to a Canadian subsidiary of the United States holding company in return for the latter's interests in the British market. While some of the general industrial and consumer goods are still to be manufactured in the Edinburgh plant as a safeguard against fluctuating demand for tyres, certain products such as golf-balls, combs and various moulded goods have been given up because of high overhead costs or severe competition. The Edinburgh plant will thus specialise on large-scale production of tyres. It was estimated that in 1958 about 2,000 workers would be employed against the 3,315 in 1951. Drastic physical reconstruction of the Castle Mills plant was begun in 1957. The need for modernisation on the congested Edinburgh site was intensified by the opening of a competing tyre factory on a relatively favorable site in the Glasgow area.

The brewing industry has to meet changing consumer tastes, notably the increased demand for bottled or canned beer – about two-fifths of the beer is now bottled against only 5 per cent in 1900 – necessitating the installation of bottling plant and more expenditure on advertising in the national market as compared with meeting the merely local demands for draught beer. More capital is also needed with the increased use of home-grown barley, for which storage and artificial drying and rush-season transportation have to be arranged. The brewer also has to extend considerable credit to public-houses and the Scottish brewer, who is also a maltster, requires more plant accommodation. The brewing industry has not only to meet changing social conditions that

strengthen the demand for bottled beer as against draught beer and increase the competition of soft drinks but also the fluctutations in demand, whether seasonal or reflecting incomes in the heavy industry areas of Scotland and Northern England. The two largest Edinburgh firms, each employing about a fifth of the total so occupied in the city and together responsible for about half of Edinburgh's production, are now closely associated financially and have thus retained their autonomy.

The baking industry has also undergone considerable reorganisation in recent years. Ten firms now employ over half those occupied in the industry and two of these employ over 200 each. As in brewing, both increased mechanisation and changing consumer habits have encouraged the growth of larger units. From the weighing of the flour to the slicing and wrapping of the loaves everything is now mechanised in the large modern bakery. High costs of installation of the new ovens and machinery has meant the overshadowing of family businesses by large 'plant' bakeries, some owned by syndicates with country-wide interests. Though Edinburgh has fewer of these large-scale units than most towns of its size the development of these bakeries has more than compensated in employment for the disappearance of a number of small firms. The increased retailing of bread outside the traditional baker's shop – by grocers, dairies and department stores as well as by vans on the new housing estates where few or no small bakers are found – also encourages the large plant. Here too there has been specialisation of old firms within new combines. One firm's chain of shops now retails bread baked by other member firms. The many small family bakeries survive largely on the production of fancy bread and cakes on which the small baker can use his skill and cater for the taste of smaller groups of customers.

Another recent amalgamation in Edinburgh was that of two leading pharmaceutical firms in 1953. Several amalgamations as well as that in the rubber industry have been accompanied by control from larger organisations outside Edinburgh and some have involved also a degree of vertical integration. Within Edinburgh various units in the grain-milling industry have recently been integrated – the largest mill at Leith docks, producing flour from imported wheat, another at Haymarket handling domestic wheat and producing flaked maize and barley as well, a third mill specialising on compound feeds, while a fourth mill is being closed. The same organisation controls two bakeries in Edinburgh, one of which produces mainly fancy cakes, and a larger bakery in Glasgow, which sends bread daily to Edinburgh. Two mills, one producing compound feeds for pigs and poultry as well as oatmeal, the other breakfast oats, at Leith and Colinton respectively, are linked to a well-known English package-salt firm, while the largest Scottish chocolate confectionery firm, one of the largest firms of any kind in Edinburgh, is linked to an equally well-known English cocoa and chocolate firm.

FACTORS IN STABILITY

The high proportion of professional and other tertiary economic

activity in Edinburgh makes the city less directly affected by any business fluctuation; the structure of its secondary industry too contrasts with that of other industrial regions in Scotland in having little development of the cycle-prone industries of the earlier industrial revolution such as textiles and the heavy industries, and so has added to this immunity from cyclical disturbance. The fifteen secondary industries with location quotients over unity fall into three approximately equal groups – food and drink, building and contracting, others – in each of which approximately 15,000 people are occupied. Individual industries too have shown in the past considerable capacity to spread their activities to allied branches or even switch over completely to these. From paper manufacture to printing, from bread and flour confectionery to biscuits are examples. Partly because of the character of its industries Edinburgh has been relatively unaffected in the past by serious industrial disputes. New industrial development was also encouraged in the past by relatively cheap electricity.

Population, industrial or other, has not in recent decades shown much growth. A number of new factories have in recent years been built but these have as often as not meant merely the substitution of a new site for an older. Replacement of a biscuit factory in Slateford by one at Sighthill, almost complete transfer of carton manufacture from a Lochend factory to one at Sighthill are cases in point. The existing proportion of basic to non-basic industry and the development of mechanisation and automation would seem to be effective brakes on expansion beyond the half-million level regarded by the planners as a desirable limit to Edinburgh's population.

In the structure of its labour-force Edinburgh has also considerable built-in stability. Not only does its large proportion of tertiary activities, notably in education, hospitals and secretarial work, both in the civil service and in business, mean much employment for women, but in several of its special industries – chocolate and sugar confectionery, manufactures of paper and board, biscuits, wholesale bottling – over half the labour is female. Facilities for commuting are also on the whole a stabilising factor. The inward movement at the time of the 1951 Census was 18,100 daily. Over two-thirds came from five to ten miles radius and their journeys to work mostly occupied fifteen to thirty minutes. Midlothian is the source of 46 per cent of this inflow and the Lothians as a whole the source of three-quarters. The outward movement at the same date was 7,900 daily. The net inward movement was thus 10,200 daily. There is also a shorter-distance daily movement between the new housing schemes inside the city boundaries and the industrial belt, especially the congested areas in Leith, where industry is more linked to port facilities and so could not move to the new housing areas.

The urban pattern of industry in Edinburgh has in recent decades shown little change save for some movement into less congested sections of the city's industrial belt. This belt has remained spatially stable and its present development is hardly likely to disturb the planners' concept of Edinburgh as a city remaining at the half-million population level.

Nevertheless it is difficult to foresee what might be the repercussions on Edinburgh of an eventual acceleration of development in the Midlothian coalfield.

A notable feature of Edinburgh's industrial belt is its lack of specialised subregions. Only brewing shows a distinct localisation within the belt. Otherwise the different types of industry are intermixed throughout. There are only six large concerns with 1,000 or more workers. Industrial linkages are increasing with other branches of highly rationalised industrial groups with interests in other parts of Britain rather than with other local firms. Edinburgh is part of a transportation nexus receiving its inflow of food and raw materials – grain, flour (even part of its bread), sugar, oilcake and meal. raw rubber and steel – mainly from Glasgow and the south. Coal comes by rail for short distances from Midlothian to South Leith and to the Portobello power station. Edinburgh is itself a supply centre for general merchandise for most of South-eastern Scotland, approximately as far as a line from Eyemouth on the south-east, through Jedburgh and Hawick, and thence northwestward to Linlithgow and Grangemouth. The Extra-mural Department of Edinburgh University, including the whole of the Lothians and the four Border counties, overlaps this line on the south and west and also occupies a small bridgehead at the north end of the Forth Bridge. Edinburgh evening newspapers circulate not only in this area but as far north as Thornton in Fife. Beyond these boundaries the most important regular outflows in bulk include whisky and beer, tyres, cartons and stationery, books and, on special contracts, heavy electrical equipment, and other heavy engineering goods such as paper-making machinery.

As in other industrial regions this is a period of adjustment to change – in consumer demands (bread and flour confectionery, brewing), new technical advances in raw materials and competitive products (rubber), conditions in consuming industries (compound feeds and fertilisers) – to name only some of the industries that have been specifically mentioned in the above brief survey. But to a considerable extent the city benefits from the buffer effect of its relatively large proportion of tertiary economic activities. These service activities would appear in fact to have been throughout its history its *raison d'être* and most of the secondary industries that have developed – the food and drink manufactures that absorb a third of the total population occupied in secondary industry, the building and contracting group that absorbs another third and even most of the remaining third, such as printing and publishing and manufactures of paper – have grown from the initial need to supply the local population, with a market extending from Edinburgh to the rest of South-eastern Scotland and, as transportation facilities improved and reputation spread, in some cases beyond. The outstanding instance of an industry that did not grow out of the city's service activities, rubber, is now undergoing a critical process of adjustment. Apart from this initial dependence of its industries on a population engaged in tertiary activities Edinburgh shows little of the linkages that would characterise a considerable industrial complex. It remains in short preponderantly a service centre.

This paper is based mainly on fieldwork carried out under the author's supervision by Miss C. Anne Chesser, Mr Albert G. Coffey and Mr Gordon H. Williamson; Mr Williamson in particular made a comprehensive survey of location and size of firm throughout the area.

[1] Waterston, Robert, Early Paper Making near Edinburgh. *Book of the Old Edinburgh Club*, Vol.25, 1946; *idem*, Further Notes on Early Paper Making near Edinburgh, *ibid.*, Vol.27, 1949.

[2] Malcolm, C. A. The Growth of Edinburgh: c.1128-1800. British Association for the Advancement of Science, *Scientific Survey of South-eastern Scotland*, 1951, p.70.

[3] *A Note on Tertiary Economic Activities:* The following table shows the tertiary branches in which Edinburgh's index of specialisation is higher than unity. The corresponding figures for Glasgow are given for comparison.

TERTIARY ACTIVITIES	Edinburgh	Glasgow
Law	4.0	3.6
All professions and services	1.6	1.2
Religion	1.6	0.8
Insurance and banking	1.5	0.9
Medical and dental	1.5	1.2
Education	1.4	1.1
Laundries	1.4	0.7
Transportation and communications	1.3	1.4
Distributive trades	1.2	1.3
Public administration and defence	1.1	0.6
Hairdressing and manicure	1.08	0.95

The outstanding feature of Edinburgh's tertiary economic activity is that it has in relation to the total occupied population double Glasgow's representation of religion, public services and laundries. This may confirm certain outside impressions of Edinburgh as a city of 'sanctimonious stuffed shirts'. The somewhat smaller representation of hairdressers in Glasgow may suggest on the other hand that the population of that city is rather more 'longhaired'. Edinburgh's higher representation in public administration and in insurance and banking conforms to its status as the Scottish capital and insurance centre.

[4] The use of the location factor or location quotient has been developed by P. Sargant Florence most fully in his *Investment, location and size of plant*, Cambridge, 1948. The index of specialisation, is used in a recent study by J. A. Sporck, *L'activité industrielle dans la Région liégeoise*, Liège, 1957.

THE GROWTH OF GRANGEMOUTH: A NOTE

DAVID SEMPLE

THE rapid growth of Grangemouth, both as a port and as an industrial area, has been one of the most striking features of the modern development of Scotland. The present note attempts no more than to show by a set of four maps the main phases in the growth of the town. While Grangemouth is centrally placed in the Lowlands of Scotland, the site was initially a difficult one and the creation of the port had to await the development of industry and commerce in Scotland. Once this had been established the site was provided with a rich hinterland, and a potentially rich foreland in Scandinavia and North-West Europe.

The low, flat, easily flooded carse-lands at the mouth of the Carron and Grange burns did not encourage early settlement other than agricultural and what shipping there was passed up the Carron to the firmer land at Carronshore, where the famous Iron Works developed. The meandering course of the lower Carron had been progressively straightened, but, it was not until a deliberate choice was made and capital had become available to ameliorate the site that a town – and seaport – became possible on the mudflats at the Grange mouth. In July 1768 Sir Lawrence Dundas dug the first spadeful of soil for the channel of the canal which was to join the estuaries of the Rivers Forth and Clyde. In its heyday, the Forth and Clyde Canal, from Grangemouth in the east to Bowling in the west, was to see the passage of as many as 3,000 vessels per year: now it is but little used and only occasionally does a fishing boat or a puffer pass along its thirty-five miles of waterway and through its thirty-nine locks. However, it gave Grangemouth its initial impetus and the momentum has been well maintained ever since.

The idea of joining the east and west across the narrow waist of Scotland had been envisaged from the time of Charles II but it was not till 1790 that the canal was completed. Dundas, who owned the ground at both ends, hoped by the project to encourage trade and saw that this would involve the construction of a seaport at the eastern end of the canal. As he had foreseen, ocean-going vessels were too large to pass through the canal and transhipment became necessary. As was to be expected, a few houses, shops and an inn sprang up to serve the needs of the ships. Thus Grangemouth began its life in 1777.

Originally the port was a small tidal harbour – the Old Harbour (Fig. 1) – but so successful was the venture that in 1836 a wet dock – the Old Dock – was opened. The volume of trade continued to increase at such a rate that another basin was soon added – Upper or Junction Dock. Grangemouth now appeared as a minature Venice with its canals, docks, and the timber basins which were constructed to store the wood imported from Scandinavia. (See Plate 1a).

In 1801 William Symington designed the engines for the world's first practical steamship, the paddle-steamer *Charlotte Dundas*, built at Grangemouth. The ship was designed for traffic on the Forth and Clyde Canal and although her maiden voyage was a complete success (she

reached Port Dundas, Glasgow, in six hours) it was decided further use might damage the banks of the canal and she was laid up. With the increasing trade of the port it is hardly surprising that a shipyard for the construction of wooden vessels was opened in 1839. Later ships were built of iron and finally steel.

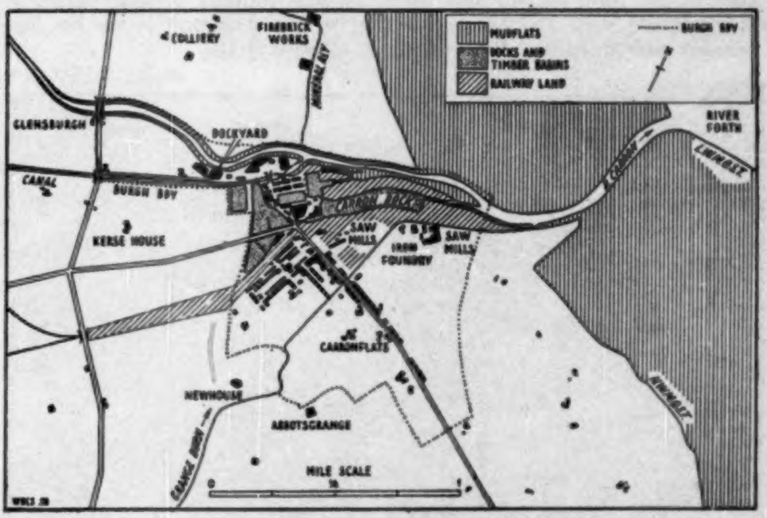

Fig. 1 Grangemouth, 1860: The Dundas Creation

The volume of traffic on the canal, sometimes complicated by freezing in winter, caused serious congestion and in 1860 a branch from the main railway line was opened to supplement the transport of merchandise and minerals to and from the docks. By 1867 the Caledonian Railway Company owned much of the Lanarkshire coalfield (then the leading Scottish producer) and was thus interested in an east-coast outlet for their Continental markets. The result was that they purchased the canal and the docks at Grangemouth.

Meanwhile the town had been growing and in 1872 it was created a burgh. Once more the volume of traffic became too great for the capacity of the docks and shipowners complained of the delay in securing berths. Plenty of marshy land was available and the underlying clays were easily excavated to form the Carron Dock in 1882 (Fig. 2). Connection with the Forth Estuary was still made via the River Carron. The dock traffic had increased from an average of 310 vessels per year in 1830/40 to 1,853 in 1874. In 1876 the total of imports and exports was 840,326 tons; 62 per cent were imports, of which timber formed 20 per cent. There were regular steamship sailings to Middlesborough, Hamburg and Rotterdam and berths were reserved for the Carron Company steamers plying between Grangemouth and London. Inward cargoes were mainly timber and grain while the exports were pig-iron and chemicals. While the traffic in the port was increasing the canal traffic was declining and the railway taking over.

The map of 1897 (Fig. 2) shows that the town had spread from the original source at the end of the canal – the Old Town – to the eastern side of the docks to what has become known as the New Town, the two being joined by bridges across the narrow channels between the docks and the timber basin. Industry has now been added to the busy port in the form of two saw mills, an iron foundry, a soap-works, a shipbuilding yard and an engineering works. The population has increased sixfold, from 1,488 in 1841 to 8,386 in 1901.

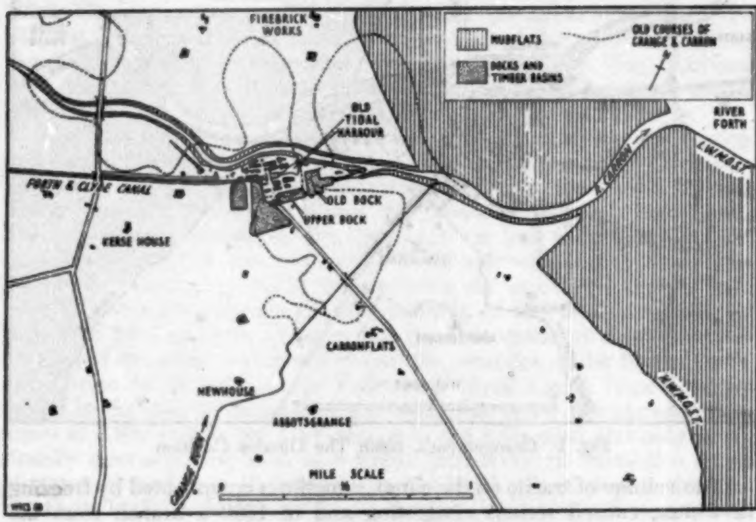

Fig. 2 Grangemouth, 1897: The Railway Port

Despite the fact that the Carron Dock had been opened in 1882 to relieve the congestion in the port, the speed of development was such that within ten years the position was as bad as ever, and serious thought was given to the idea of cutting a new entrance away from the River Carron. This involved considerable reclamation but in 1906 the new Grange Dock was opened with a lock to allow ships to enter from the Firth of Forth. (Fig. 3). By this time the annual volume of trade exceeded 2.5 million tons.

The growth of the town continued steadily until 1919 when a new phase in industrial evolution began, albeit in a small way. Vat dyestuffs were manufactured at Carlisle by Scottish Dyes Limited, but the factory became inadequate for expanding business and a new site was necessary. Grangemouth was chosen as the site, for what has become known, locally, as "the Dyeworks", mainly because of the availability of water supplies and labour, and good road, rail and sea connections.

A few years later in 1924 Scottish Oils Limited, which had grown out of the shale oil industry of West Lothian, opened a refinery in Grangemouth to handle crude oil imported by sea from the Middle East. Further additions were made to the dock installations to enable the

Pl. 1a. *(above)* Grangemouth, from the south-east; inner docks with timber basins and shipbuilding yards (cranes centre); rich carse-lands beyond and Highland-Front in extreme background. *Aerofilms, Ltd.*

Pl. 1b. *(below)* Grangemouth from the north-east: outer dock basins between mudflats of Forth (foreground) and Carron River (right); Forth-Clyde Canal (right centre); Carron Iron Works smoking in right distance. *Aerofilms, Ltd.*

A. D. S. Macpherson, Stirling

Pl. 2. Forth carselands, looking north-west from Stirling Castle to Flanders Moss (wooded) in centre distance; Highland Front in distance with (left to right) Ben Lomond, Ben Venue and Ben Ledi; Small wooded volcanic hill right centre; edge of Gargunnock Hills left centre. The flat carse lands are raised ('neolithic') beaches reclaimed in the eighteenth and nineteenth centuries from peat covering — at first on a small scale by letting to displaced Highlanders, later reclamation and reorganisation produced the present large regular field pattern.

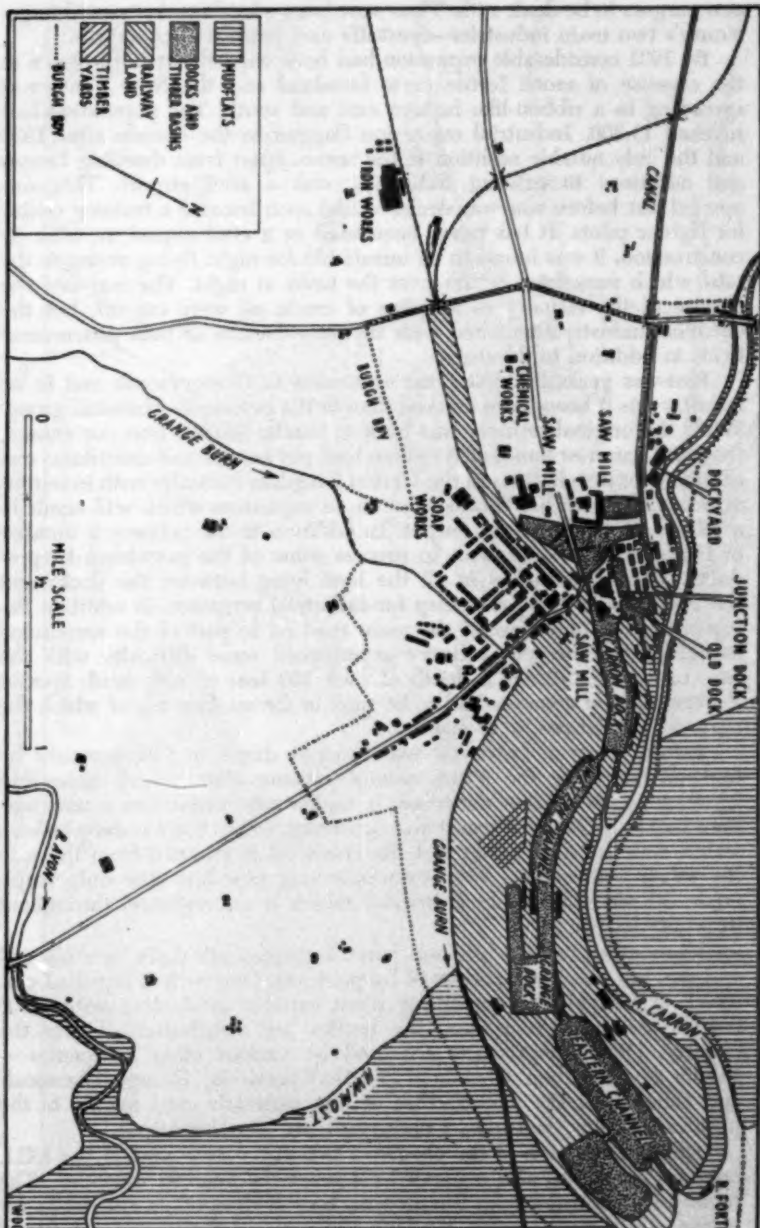

Fig. 8 Grangemouth, 1921: The Mature Port

new cargoes to be dealt with. Thus were born what have become Grangemouth's two main industries—dyestuffs and petroleum-chemicals.

By 1931 considerable expansion had been carried out in the town at the expense of much fertile carse farmland and the New Town was spreading in a ribbon-like fashion east and south. The population had reached 11,800. Industrial expansion flagged in the decade after 1930 and the only notable addition to the scene, apart from dwelling houses and additions to existing industries, was a civil airport. This was opened just before war was declared and soon became a training centre for fighter pilots. It has never been used as a civil airport as, after its construction, it was found to be unsuitable for night flying owing to the mist which sometimes settles over the town at night. The war saw the closure of the refinery as supplies of crude oil were cut off, but the chemical industry flourished with the manufacture of bulk pharmaceuticals in addition to dyestuffs.

Post-war years brought great expansion to Grangemouth and in no industry has it been more marked than in the petroleum-chemical group. While the original refinery was built to handle 360,000 tons per annum, the plant can now handle 2.5 million tons per annum and constitutes one of the major installations in the United Kingdom (actually sixth in output at present). Work has commenced on an expansion which will result in a 50 per cent increase in output. In addition to the refinery a number of factories have been built to process some of the petroleum by-products. This has resulted in all the land lying between the docks and the River Avon being taken up for industrial purposes; in addition the expansion has now crossed the main road on to part of the aerodrome site (Fig. 4). The new refinery experienced some difficulty with the site, on which there is a depth of over 100 feet of silty mud. Special floating rafts of concrete had to be sunk in the mud on top of which the various installations were erected.

Before the war, crude oil was brought direct to Grangemouth by tankers, but since the jetties cannot accommodate vessels exceeding 12,000 tons, the post-war increase in tanker size meant that a new harbour had to be found. Finnart on Loch Long, where there is deep inshore water, was the site chosen and the crude oil is pumped from there to the refinery through a fifty-seven-mile-long pipe-line (the only major crude oil pipe-line in Great Britain) which is underground throughout its whole length.

The various refined products leave Grangemouth daily by road, rail and sea, but there is a variety of by-products. One such is liquified gas, which is bottled at a gas-filling plant capable of dealing with 2,800 bottles per day. From there the bottles are distributed all over the country. Other by-products are used by various other companies – British Hydrocarbon Chemicals, Forth Chemicals, Grange Chemicals and Gemec, for the manufacture of raw materials used mainly in the plastics industry. Household detergents are also important.

The other branch of the chemical industry – now part of the I.C.I. organisation – has also expanded considerably since its inception. The factory is concerned with the manufacture of dyes of various kinds for cotton, wool, rayon, nylon, terylene and paper: pigment for paints and plastics: and bulk pharmaceutical products. Of the products 40 per cent

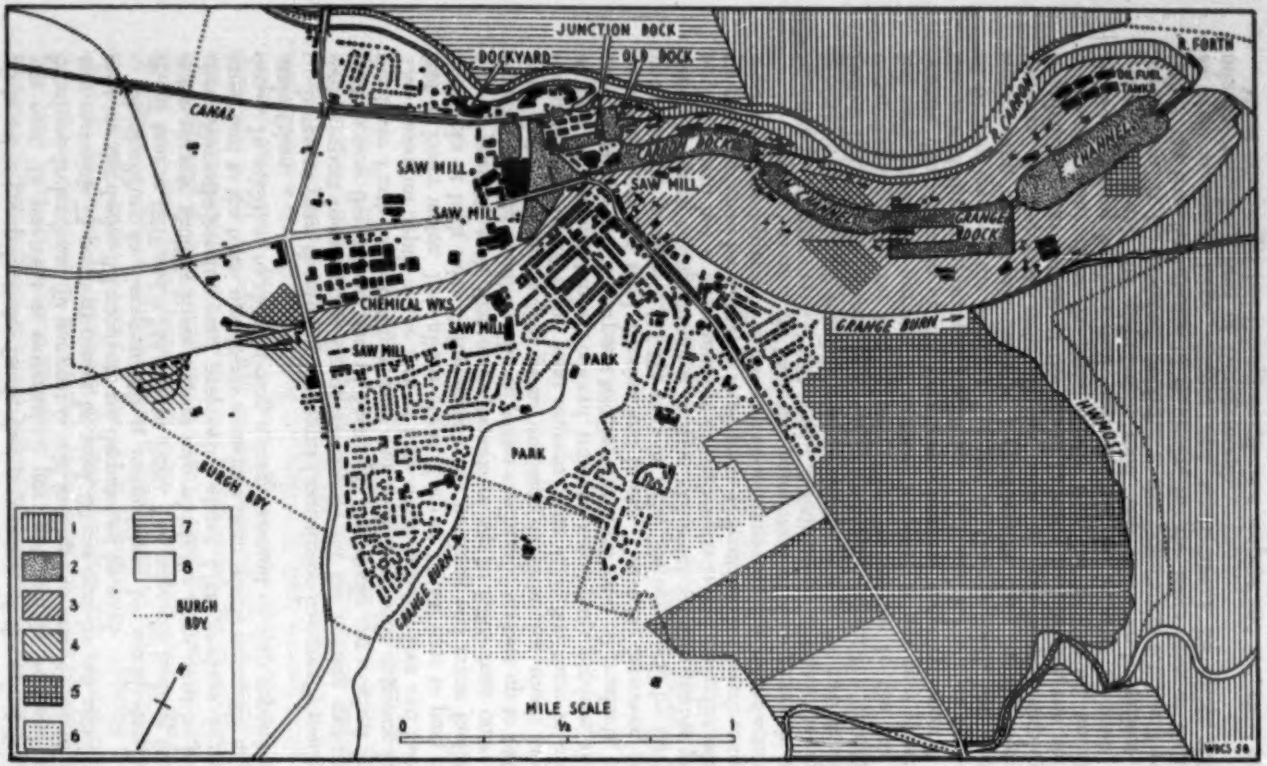

Fig. 4 Grangemouth, 1958: The Petroleum-Chemical Era.
1. Mudflats; 2. Docks and timber basins; 3. Railway land; 4. Timber yards; 5. Petroleum-chemical installations; 6. Future building (residential); 7. Future building (industrial); 8. Parks, green belt, etc.

go to other group factories for further processing; of the remaining 60 per cent, 18 per cent is exported, 3 per cent sold in Scotland and Northern Ireland and 39 per cent is sold in England and Wales. Of the raw materials 75 per cent comes by road, 20 per cent by rail and 5 per cent via the docks. All products are despatched by road.

Shipbuilding in Grangemouth is insignificant by world standards (6,467 tons in 1957 and 8,753 tons in 1956). The principal limiting factor is the narrow, shallow River Carron into which the ships must be launched. Nevertheless the yard, employing about 1,000 workers, is quite important to the town, and forms a nucleus from which expansion might occur. In addition to shipbuilding a large amount of ship repairing is undertaken.

In recent years the British Transport Commission has greatly modernised the port installations. Grangemouth, by far the leading east-coast port, is now the second port of Scotland. The docks are reached from the River Forth via a 626-foot long and an 80-foot wide entrance lock. The maximum depth of the lock at high water is thirty feet and twelve feet at lower water. This allows ships of up to 14,000 tons to pass into the docks at high tide. Unfortunately the berthing and crane facilities are, at present, such that cargo vessels of up to 8,000 tons only are capable of being handled. The oil jetties can handle tankers up to 14,000 tons. Future modernisation plans envisage facilities for much larger cargo vessels. In 1957 the total imports were 1,732,844 tons: in order of greatest tonnage, timber, cement, iron-ore, wood pulp, pig-iron, silver sand, esparto grass; the exports totalled 1,667,436 tons: oil products, coal and coke, iron and steel, fireclay and bricks. This total, however, does not reach the peak of 4,217,514 tons in 1923. Timber is still by far the leading import. Grangemouth is, in fact, the chief Scottish timber port, and the town has a large number of timber-yards and sawmills which prepare the wood for despatch to all parts of Scotland, for constructional work and for pit-props. Window and door-frames are also manufactured.

At a special census in 1957 the population of Grangemouth was found to be 17,800 (1931–11,800: 1951–15,300) which indicates the rapid growth in the past six years as compared with that in the two decades before 1951. These figures, however, do not fully reflect the industrial expansion involved, for two reasons; first, in relation to the size of the new plant, the number of workers involved is not very great, a feature characteristic of the petroleum-chemical industry: second, in the case of the two principal employers (I.C.I. and B.P.C.), an average of 61 per cent of the workers live not in Grangemouth but in the surrounding district, *i.e.* there is a considerable daily immigration of workers. By contrast, only 12 per cent of the burgh's employed population works outside of the town. Industry has, in fact, run ahead of housing and there is little doubt that, as residential building proceeds, many workers will come to live in, as well as work in, Grangemouth and its population total will more truly reflect its importance. It is, however, doubtful if the population total will ever reflect the true importance of the town, for the large town of Falkirk as well as many large villages and small towns lie within thirty minutes travelling time of Grangemouth.

What advantages has Grangemouth as a seaport and industrial site?

These are various. It is equidistant between Glasgow and Edinburgh and within easy reach of all industrial Scotland by road and rail. Overseas connections have been established to such an extent that world markets are now conveniently accessible by means of its shipping. Recently, for example, the P. and O. Line has made Grangemouth its Scottish cargo terminal with monthly sailings to the Orient and to Australia. Other advantages are a good water supply and easy access to the Scottish coalfields. There is an abundance of flat land for building including considerable frontage on the Firth. Provision has been made for the accomodation of heavy industry *e.g.* a steel-strip mill, to the north-west of the River Carron on what is at present excellent farming land. (See Plate Ia). In addition there is a considerable extent of mud which is exposed at low tide and which could be reclaimed when the demand for land begins to exceed the supply. (See Plate Ib). With such advantages Grangemouth may well, as growth continues, become the nucleus of a large industrial conurbation.

NOTICES

The Honorary Degree of Doctor of Laws was conferred on Dr Douglas Allan, C. B. E., President of the Royal Scottish Geographical Society by the University of Edinburgh on the 3rd of July, 1958.

Fifty boxes of Dr. Bruce's photographic negatives (all stereo-pairs) taken on the *Scotia* Expedition to the Antarctic and elsewhere have been presented to the Royal Scottish Geographical Society by the Royal Botanic Gardens Edinburgh.

LANDSCAPE EVOLUTION IN THE OCHIL HILLS

Jane M. Soons

SINCE the later years of the nineteenth century, when some of the classical works on the Scottish landscape were written, a number of conflicting views have been published on the manner in which it may have attained its present form and, in particular, on the possible origin of the drainage pattern. Peach and Horne, [1] following Sir H. J. Mackinder, [2] envisaged a series of north-west to south-east consequent rivers, developed on a land surface planed off and tilted south-eastwards. Later, both A. Bremner [3] and D. L. Linton [4] suggested that a system of west to east consequents initiated on a newly emerged surface was more in keeping with the facts observable in the present landscape, while in the Southern Uplands the apparently stepped nature of the upland surfaces has been attributed by S. E. Hollingworth [5] and T. N. George [6] to marine planation during a series of intermittent uplifts of the land-mass, the development of the drainage pattern being consequent on this uplift.

It may be noted that these views have in most cases been based on a study of features in either the Highlands or the Southern Uplands or in both, but some difficulty has arisen in the extension of any particular hypothesis to the Lowlands, as a result of the nature of the area. Here elevations are generally much below those of the upland areas, and the broad valleys show more evidence of the efficiency of recent glacial deposition than of earlier stages in their development. Yet any valid account of the development of the landscape must apply to this area also, and the evidence that is to be found in the various hill masses cannot safely be ignored, even if it is more limited in amount than that provided by the more extensive upland areas. In this respect the Ochil Hills are of particular importance. Rising to heights greater than those of any other Lowland hill mass (to 2,363 feet O.D. in Bencleuch) and running for twenty-five to thirty miles in a south-west to north-east direction from the Forth at Stirling to the Firth of Tay, they offer a wide area in which upland surfaces and traces of early drainage patterns may be sought.

The amount of published material on the Ochils is small. Sir Archibald Geikie in 1900 described the geology of part of the area, but was not greatly concerned with the development of its drainage pattern [7]. In 1916 J. E. Wynfield Rhodes drew attention to the alignment of Glen Lednock with Glen Eagles, and of Glen Devon with the valleys of the Gairney Water and the Fifeshire Ore, which seemed to him to be evidence of a north-west to south-east consequent river, dismembered by piracy along structurally favourable lines. [8] Thus a tributary of the Earn was assumed to have worked back along the sedimentary strata north of the hills to divert the Glen Lednock-Glen Eagles stream near Muthill, reversing the drainage of Glen Eagles, while the lower Devon worked back along the line of the Ochil Fault to capture the middle section of the consequent and produce the remarkable elbow bend of Crook of Devon (Fig. 1). A number of valid objections to this hypothesis

were advanced in 1940 by Linton, [9] who pointed out that Glen Eagles has the form of a typical glaciated trough, and was probably developed by a diffluent lobe of ice lying to the north of the hills. [10] Piracy by the lower Devon on the lines suggested by Rhodes is shown to be improbable, the river being in no way controlled by the Ochil Fault, and the Crook of Devon bend is attributed to "a very recent diversion at the margin of a stagnant portion of the last ice-sheet." [11] Recent field investigations have revealed that a well-marked valley in the fluvio-glacial deposits of the area now occupied by the Gairney Water continues south-eastwards from Crook of Devon, and that there are no traces of dead ice in a position which might have caused such a diversion. It is, however, obvious that this part of the Devon is wholly post-glacial, although its development may have been more complicated than Linton appears to envisage.

Fig. 1 Ochil Region: place names referred to in the text.

Linton's own reconstruction of the possible early drainage pattern is based on the broad high-level valley benches which are found above Glen Devon, and on wide cols at corresponding levels at either end of the west-east flowing section of the Devon [12] (Fig. 2). These features are regarded as evidence of the existence of a long west-east stream of which the Devon is but a remnant, and which formed one of a series of west to east consequent rivers. The Water of May and other north-flowing streams in the central hills are considered to have originated as tributaries of the early Earn.

The present landscape of the Ochils is dominated by deeply cut, narrow valleys above which are found old valley benches such as those cited by Linton, and extensive remnants of early erosion surfaces (Fig. 2). These last give the hills a decidedly plateau-like appearance in almost

any distant view, which is emphasised by the steep slopes rising from the surrounding lowlands. Above the lower Devon valley the impressive southern scarp face is closely associated with the Ochil Fault, and rises from the carse lands to 1,600-1,700 feet O.D. (See Plate 3). The fault, with an estimated throw of 5,000-10,000 feet, [13] has juxtaposed resistant Lower Old Red Sandstone andesitic lavas, of wich the hills are formed, and Carboniferous sediments forming the lowland to the south. The northern scarp face overlooking Strath Earn is lower but of similar origin, although here the throw of the fault concerned is less. A small area of Carboniferous sediments occurring on the north side of this fault (Fig. 3) was regarded by Geikie as evidence of a former cover of Carboniferous and possibly younger rocks over the Ochils. [14]

The andesites have been gently arched to form a broad anticline trending south-west to north-east but slightly oblique to the trend of the hills (Fig. 3). In the east the northern limb of this anticline forms the Sidlaws, while the low eastern extension of the Ochils south of the Firth of Tay is developed on the southern limb. Between the two is the down-faulted area of the Carse of Gowrie and lower Strath Earn. In the central and western Ochils the southern limb has no physiographic expression comparable to that of the northern, the high ground in the west being developed entirely on strata dipping north-westwards. This must in part be due to the Ochil Fault, truncating the anticline, but the fault coincides with the edge of the hills for only ten to twelve miles, and east of Dollar curves south-eastwards to the Cleish Hills. Between these hills and the Ochils the relatively low Plain of Kinross has been developed across part of the southern limb, contrasting strongly with the high relief normally associated with the andesites. The eastern part of the plain, containing Loch Leven, is developed on Upper Old Red Sandstone strata which rest unconformably on the volcanic series. It is possible, therefore, that the andesites of this area were lowered to very much their present level prior to the deposition of the younger rocks. Both around the Ochils and elsewhere there is evidence of considerable denudation of the Lower Old Red to give a surface of variable relief on which later rocks were deposited, but the influence of this surface on present relief is usually slight.

The influence of geology on the drainage pattern and relief of the hills appears to be limited, apart from the broad association of upland and resistant rocks. Although there are considerable differences in the resistance to weathering of the individual lavas, tuffs and agglomerates, these change rapidly over short distances and are effective on only a small scale, giving rise to minor features but apparently never controlling the direction or location of valleys. A few valleys are guided by known faults; these are usually of relatively recent origin – chiefly spillways, of which Glen Queich is perhaps the finest example. A much larger number of valleys are, however, arranged in a surprisingly rectilinear

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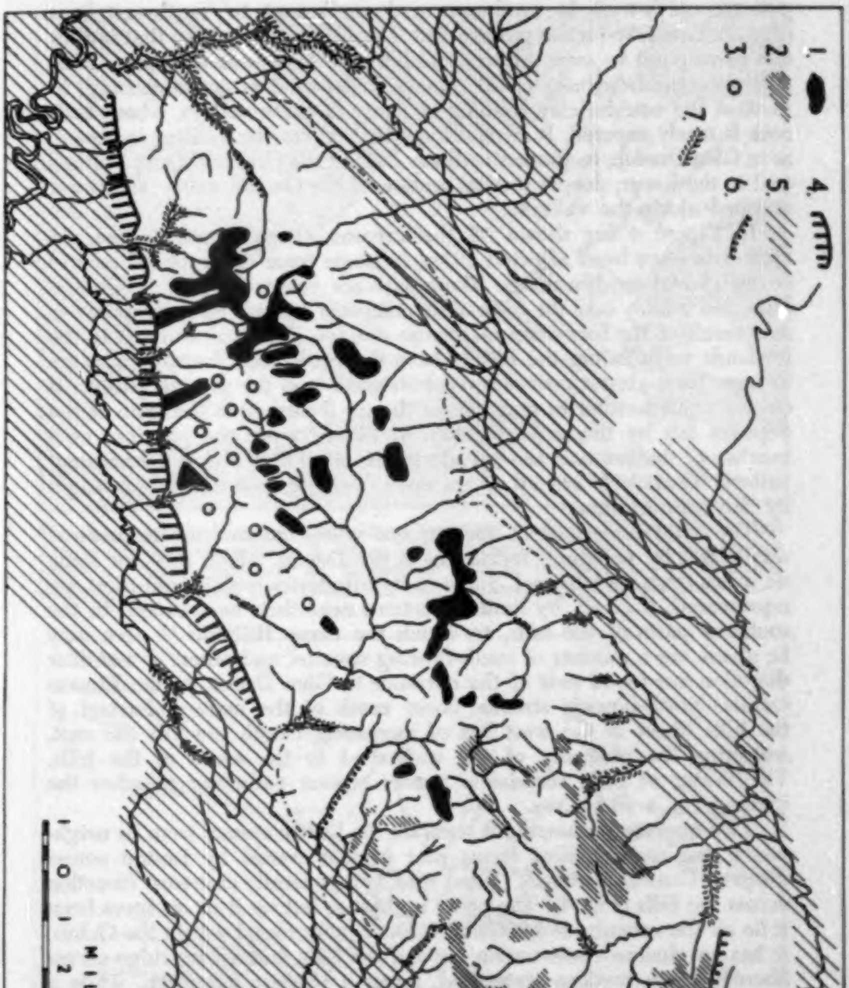
Fig. 2. (opposite) Major morphological elements of the Ochil region.
1. Ochil Main Surface; 2. Ochil Lower Surface; 3. Summits of 2,000 feet and over; 4. Scarps; 5. Areas in which drainage pattern is largely of post-glacial origin; 6. Streams whose direction is determined by meltwater channels; 7. Gorges.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pattern, north-west to south-east and south-west to north-east lines (Fig. 3). So marked is this pattern that it is difficult to believe that it does not correspond to some hitherto undetected structural weakness. That such structural features could remain undetected is not surprising, in view of the boulder-clay infilling of many of these valleys, where bed-rock is rarely exposed. It is significant that where the infilling is absent, as in Glen Queich, in another spillway linking the Care and Quey valleys, and in the lower, deeply incised section of the Gannel valley, faults are mapped along the valleys.

In Figure 4 are shown all the streams whose direction does not appear to have been affected either by some form of structural control or by glacial modifications. These last are relatively few within the hills, and usually take the form of diversions of streams through spillways as a result of the formation of corrom divides. This is in contrast to the lowlands surrounding the hills, where the pre-glacial drainage appears to have been almost everywhere obliterated, and the present pattern is closely related either to positions of the ice-fronts, or to the form of the deposits left by them. Also shown in Figure 4 are the positions of a number of shallow cols across watersheds, often high above the adjacent valleys. These cols are all of an open V-shape, pointing to an origin by fluviatile erosion.

The most important of the streams whose courses are apparently unaffected by structural influences is the Devon, which runs for some six miles from west to east. Some of its tributaries remain, but most are represented, if at all, by limited portions near their headwaters. In the southern parts of the hills, to which the name Hillfoots [15] area may be given, are a number of south-flowing streams, and others of a similar direction are found east of the entrance to Glen Devon, in the Kinross Ochils. North-flowing streams occur north of the main watershed of the hills, short in the west but of increasing length towards the east, reflecting the obliquity of the watershed to the trend of the hills. The Water of May remains a master stream gathering together the drainage of a wide area.

Two important watersheds separate the Devon system from its neighbours; the northernmost forms part of that traced by Linton across much of Central Scotland, [16] and runs in a generally east-west direction across the hills (Fig. 4). The other is shorter, but on it or on spurs from it lie all the summits of 2,000 feet O.D. or more found within the Ochils. It has no obvious continuation beyond the hills, but a long ridge across Sheriffmuir, a modern watershed, forms a western extension, while a line of low hills between the Ochils and the Cleish Hills appears to extend it eastwards. This line is now crossed by the Devon and by two or three smaller streams of varying size, but all except the Dollar Burn are of post-glacial origin. Even the Dollar Burn may be of recent origin, although the occurrence of boulder clay within its gorge indicates its existence prior to the last glaciation of the area. A broad valley runs eastwards from the point at which the Burns of Sorrow and Care combine to form the Dollar Burn, about 100 feet above the streams but approximately at the level of a bench below which the gorge is cut. This valley has been much modified by glacial deposition and later stream action, but it seems probable that it may have carried the Burns

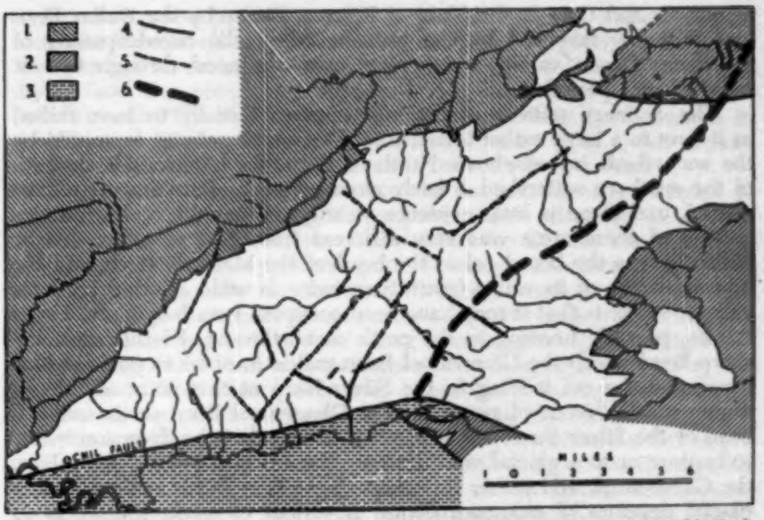

Fig. 3 Generalised geology and major structural features: 1. Lower Old Red Sandstone Sedimentary rocks; 2. Upper Old Red Sandstone rocks; 3. Carboniferous rocks; 4. Faults, cross-mark on downthrow side; 5. Inferred lines of structural weakness; 6. Anticlinal axis; Lower Old Red Sandstone igneous rocks unshaded.

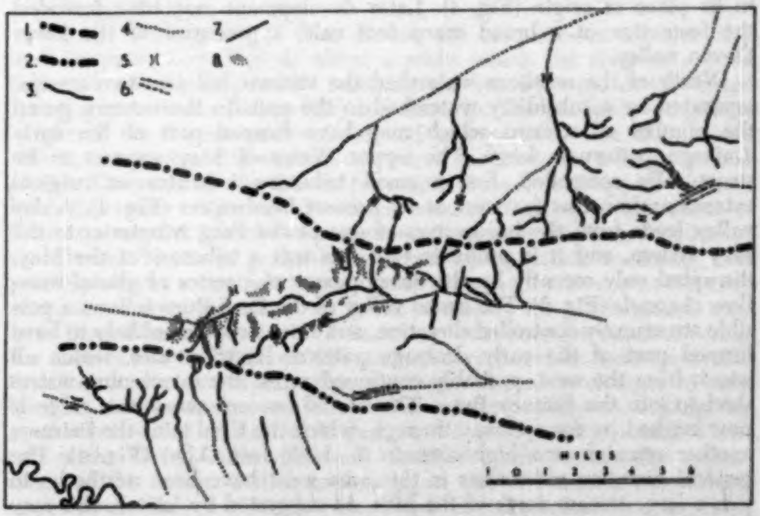

Fig. 4 Reconstruction of possible early drainage pattern: 1. Northern Ochil watershed (after Linton); 2. Southern Ochil watershed; 3. Streams whose direction is apparently uninfluenced by either structure or glaciation; 4. Reconstructed stream courses; 5. Col; 6. Through valley not now occupied by a stream; 7. Sauchanwood-Core Hill and Mellock Hill-Lendrick Hill Cols; 8. Devon valley benches developed prior to the abandonment of the Sauchanwood-Core Hill Col.

of Sorrow and Care to the Plain of Kinross. Piracy by the Dollar Burn was probably favoured by the pronounced glacial overdeepening of the lower Devon valley, which may have continued through two or more glacial periods.

The drainage pattern of the hills appears initially to have fallen, as it does to a large extent today, into three main systems, separated by the watersheds traced above. North of the main watershed and south of the southern watershed a fairly close network of streams may have existed, and there is little evidence to suggest that the early drainage pattern of these areas was very different from that of today. In the Hillfoots area the broad col at the head of the Menstrie Burn, and the unusual width of its valley (more than twice as wide as other Hillfoots valleys) suggests that it may have been occupied by a longer and larger stream, possibly heading to the north or north-west. Further east, the sharp bend which the Glenwinnel Burn makes in order to join the Alva Burn, and the col leading to the Silver Burn at this point are strong arguments in favour of regarding the Glenwinnel Burn as the original head of the Silver Burn, but it is not clear whether the diversion is due to capture or to a glacial modification. The col is about 100 feet above the Glenwinnel, and rather less above the Silver, but it is floored with glacial deposits of unknown depth. A system of small, south-flowing streams may thus be postulated for this area, possibly joining a major consequent, a fore-runner of the Forth, to the south of the region considered. A larger stream may have crossed the western end of the hills along the line of the Menstrie Burn, but there is no evidence as to its place of origin (Fig. 4). Later development may have included the formation of a broad scarp foot vale, a precursor of the lower Devon valley.

North of the northern watershed the streams fall into two groups, separated by a subsidiary watershed in the east. In the western group the number of streams which may have formed part of the early drainage pattern is large. The upper Water of May appears to be structurally controlled, but a small tributary indicates an original extension almost as far west as its present headwaters (Fig. 4). A dry valley leads from the headwaters of one of the Farg tributaries to the May system, and it is probable that this was a tributary of the May, disrupted only recently by the development of a series of glacial overflow channels (Fig. 2). The broad valley of the Coul Burn follows a possible structurally controlled direction, and this stream is unlikely to have formed part of the early drainage pattern. Its tributaries, which all join it from the west, probably continued across the intervening watershed to join the Pairney Burn. The site of one col across this ridge is now marked by the spillway through which the Coul joins the Pairney; another remains at a high altitude (*c.* 1,300 feet O.D.) (Fig. 4). The general direction of streams in this area must have been northerly, to join a large stream north of the hills. As suggested by Linton, this may have been the predecessor of the Earn.

In the extreme east of the area north of the northern watershed several small streams have an easterly or south-easterly direction, and are aligned with a number of cols and dry valleys east of, and 50-100 feet above, the Farg-Eden through valley. This through valley appears

to be a composite feature, possibly in part structurally guided, in part a normal stream valley, and certainly modified by glacial meltwaters. The present watershed between the Farg and the Eden is a corrom divide, and the pre-glacial watershed may have been some distance further north. The various east-flowing streams may have drained to the Howe of Fife by the broad Balcanquhal valley (Fig. 4) but a more detailed study of the area than has yet been made is needed.

Between the two major watersheds of the hills there is evidence of considerable changes in the drainage pattern from what may have been its original form. Such changes chiefly affect the Devon. The high-level cols noted by Linton appear to point to early extensions of the river beyond the hills. That in the west, between Sauchanwood Hill and Core Hill (Fig. 4), implies an extension across the valley of the Danny Burn, which is largely developed along lines suggesting some degree of structural control. Certain flattenings on the long spur separating the Danny Burn from Sheriffmuir may represent a further extension of the Devon, and as they can be followed round the hillside to merge with the area of gentle slopes around the Danny headweaters, this upper part of the stream may have been a small tributary of the Devon. No evidence has been found of the position of the Devon headwaters. These may have been, as Linton suggests, considerably further west, but the narrowness of the Devon drainage basin, as indicated by the major Ochil watersheds, and the possibility that a fairly large stream from the west or north-west followed the line of the Menstrie valley, make it probable that the Devon rose no great distance west of its present headwaters.

At the eastern end of Glen Devon the col between Mellock Hill and Lendrick Hill (Fig. 4) offers a route which the river may have followed eastwards, possibly reaching the sea by way of the broad Leven gap between Bishop Hill and Benarty. The probable pre-glacial height of the lowest point of this col was *c.* 1,000 feet O.D., some 400 feet lower than the western col, which may indicate a longer period of use. Diversion of the Devon from this route would appear to have been the result of piracy by a small stream draining to the Plain of Kinross along the line of the present north-west to south-east section of the Devon. This was probably favoured by structural weakness, and possibly also by a contrast in rock type. Whereas the Devon at the time of capture must have cut down to the andesites, the pirate stream may have flowed for at least part of its course over younger strata covering the andesites of the Plain of Kinross, and may therefore have been able to adjust itself more rapidly than the larger stream to changes in base level. A curious feature of this area is a broad valley continuing the north-south valley of the South Queich, but occupied by a small tributary of the Devon. Although much modified by meltwaters, the appearance of this valley is such as to suggest that it formerly carried the upper South Queich to the Devon. Yet, if capture occured on the lines suggested above the South Queich might have been expected to continue along the abandoned course of the Devon. That it did not do so, or at any rate did so for only a short time, is indicated by the probable height of the former col above the floor of the north-south valley (nearly 300 feet). A second capture, this time of the South Queich, taking place on

a north-south line not long after that of the Devon, may explain these features.

Various changes appear to have taken place among the Devon tributaries. Many of these have the strongly marked south-west to north-east alignment already noted as possibly due to structural control. The watersheds between these deeply cut valleys are crossed by a number of broad but definite cols. One such col crosses the ridge between the Broich and Frandy valleys at 1,490 feet O.D., and another crosses the Frandy-Sherup ridge at 1,400 feet O.D. (Fig. 4). Aligned with these cols is one of the Broich tributaries, and it seems highly probable that this stream may have continued in its present direction to join the Devon some distance further east. On the northern side of Glen Devon more cols are found, and a tributary may have existed following the course shown in Figure 4. It is noticeable that all the diversions entailed in converting a pattern such at that shown in Figure 4 to that of the present day are along lines which may be attributed to structural weakness.

East of the Mellock-Lendrick col the small streams of the Kinross Ochils have been modified by the development of meltwater channels, and previously may have had a more southerly direction. When the Devon flowed eastwards across the col they probably functioned as left-bank tributaries, comparable to those in Glen Devon.

The drainage pattern reconstructed above, and shown in Figure 4, differs in many respects from that of today, but even so cannot be claimed as a complete picture of what may have been the initial pattern of the area. A number of streams have been reconstructed, but others may have existed of which no trace has been found. In particular, the absence of left-bank tributaries of the Devon west of Glen Eagles raises many questions It is of course possible that the col across which Glen Eagles must have been cut, and that still remaining at Glen Bee, may represent such tributaries, of which all other evidence has been destroyed in the opening out of the subsequent vale of Strath Allan.

The modification of this early drainage pattern has clearly taken place at a number of different stages in the development of the landscape, of which evidence remains in a succession of upland surfaces and valley benches. The highest of these, the Ochil Main Surface, covers a wide area of the western hills. Of gently undulating form, it has an inner edge of variable height, rising to 1,800-1,900 feet O.D. at the foot of the higher hills along the southern watershed, and falls to 1,500 feet O.D. about Innerdouny Hill in the central hills. The highest valley benches of the Devon are clearly part of this surface, which appears to have been formed by the Devon and its tributaries at the expense of some higher surface of which the hills of the southern watershed may be remnants. At this stage the drainage pattern may have been much as suggested in Figure 4, for no evidence of changes in it have been found at this level. The various cols described above were clearly abandoned at later stages. Valley benches above Glen Devon show that after the formation of the Main Surface there were two falls in base level, in response to which the Devon cut successively deeper but broad and relatively shallow valleys. Most of the changes in the drainage pattern seem to have taken place during or immediately after the second of these stages. The Mellock-Lendrick col seems

however to have been used for a longer period, and may not have been abandoned until a third or later stage. This is indicated by the occurrence of well-marked benches along the suggested course by which the Devon must have reached the col, and presumably formed by it, at lower levels than the benches of the first two stages. Evidence of later stages is slight being provided only by small discontinuous benches along the sides of Glen Devon. The broad valleys of the earlier stages must therefore have been replaced by a series of much narrower forms, in which down-cutting became more important than valley widening.

The Ochil Main Surface has not been traced far into the central hills (Fig. 2). It is succeeded here by two less important surfaces, developed mainly along the watersheds. The highest of these, called the Simpleside Surface because of its development in the neighbourhood of the hill of that name, ranges between 1,450 feet and 1,300 feet O.D. A second surface may be represented by a number of spurs and hill summits ranging in height from 1,300 feet to 1,200 feet O.D., but always clearly separated from the higher surface. Neither of these surfaces is sufficiently extensive to carry much evidence of changes in the drainage pattern, although a col between the Coul and Pairney valleys on the Simpleside Surface indicates that the Coul tributaries may then have joined the Pairney. The low height range of these two surfaces suggests that they may correspond to the two Devon valley stages below the Ochil Main Surface. Below them valley benches are more continuous and offer more evidence of later stages in valley development than do the small remnants in the western hills. This development appears to have proceeded by the cutting of broad and fairly open valleys, in strong contrast to those apparently being formed in the western hills at the same time. The upper valley of the May is an exception, and resembles the valleys further west in that only narrow benches remain here. Over the area between the May and the Farg a very well-marked erosion surface has been formed, which in view of its extent may be termed the Ochil Lower Surface (Fig. 2). Covering a wide area, it rises to heights of over 1,000 feet O.D. along the main watershed, falling to 800-900 feet O.D. along the May-Farg watershed, and to 750 feet O.D. where it slopes down gently to the larger valleys. Although very much roughened by the passage of ice and by meltwaters it appears to resemble the Main Surface in being of subaerial origin. This is supported by the possibility of tracing the surface up the upper May valley in the form of valley benches (Fig. 2).

Evidence has been found of three later stages, during which successively lower valleys were formed. During one of these the May must have been diverted from a northerly course to give the sharp elbow-bend westwards at Ardargie. The gorge by which the stream descends to Strath Earn begins immediately upstream of this bend (Fig. 2), but a series of spillways in descending order from east to west across the ridge north of the gorge points to a pre-glacial slope in this direction, and the gorge should probably be regarded, therefore, not as evidence of capture but of recent adjustment to a lowered base level.

In many valleys throughout the hills the streams have succeeded in cutting through the glacial deposits to expose the underlying rock. This suggests that pre-glacially base level was much the same as that

obtaining today. The numerous gorges found within the hills, apparently contradicting this statement, are of post-glacial origin, in most cases being due to the infilling of a former channel, and diversion of the stream across the side or a spur of its former valley. This does not apply to the well-known gorges by which the Hillfoots streams descend to the lower Devon, which may reflect the pronounced glacial over-deepening of this valley. A pre-glacial surface in this area at approximately the same level as the low ridge separating the Devon and the Forth is indicated by a narrow bench along the scarp foot from Alva eastwards, rising from 200 to 400 feet O.D. near Dollar. Evidence of severe glacial erosion is provided by the roughened scarp face, by the 'crag-and-tail' form of the line of small eminences between the Ochils and the Gargunnock Hills, and by the so-called Devon Buried Channel, deepened to some 300 feet below sea-level (Fig. 1). This was regarded by Cadell [17] as of fluviatile origin, but recent borings in the area have revealed that the channel is formed of two deep basins separated by a low ridge, and therefore a glacial origin seems probable. The lower May gorge and other gorges in a similar position along the northern edge of the hills, including that of the Farg, may have had an origin similar to that of the Hillfoots gorges, *i.e.* resulting from glacial lowering of Strath Earn.

The evidence which makes it possible to outline the evolution of the Ochils, and which may also throw light on that of other areas, falls into two parts. There is first the drainage pattern, probably originating as part of a system of generally east-flowing consequent streams joined by tributaries from north and south, and initiated on a surface of which no traces have been found. Secondly, there are the upland surfaces and valley benches. Two dominant surfaces have been recognised in the area, together with valley benches indicating long-continued adjustment to an intermittently falling base level. Neither the surfaces nor the drainage pattern appear to be consistent with a marine planation of the area. Rather the drainage pattern appears to have been gradually superimposed upon the igneous rocks, and to have produced the broad valleys and low relief of the surfaces during periods of relative still-stand. A certain amount of adjustment to structure has taken place, particularly in the western hills, which may have been less thickly covered by younger strata than the lower areas, so that structural weaknesses were revealed at a period when the streams occupied shallow valleys from which they might be more easily diverted.

A certain contrast between the western and eastern hills has been noted, which is particularly associated with the development of the Ochil Lower Surface. This surface is widespread in the central hills, in the area draining to Strath Earn, but is represented by only narrow valley benches in the Kinross Ochils, and cannot be recognised in the western hills. Such a contrast most probably reflects the differing size of the master streams in each area. The surface is best developed in the area draining to what must always have been a very powerful river, capable of adjusting itself rapidly to changes in base level, which would be almost as rapidly reflected in the valleys of its tribut-

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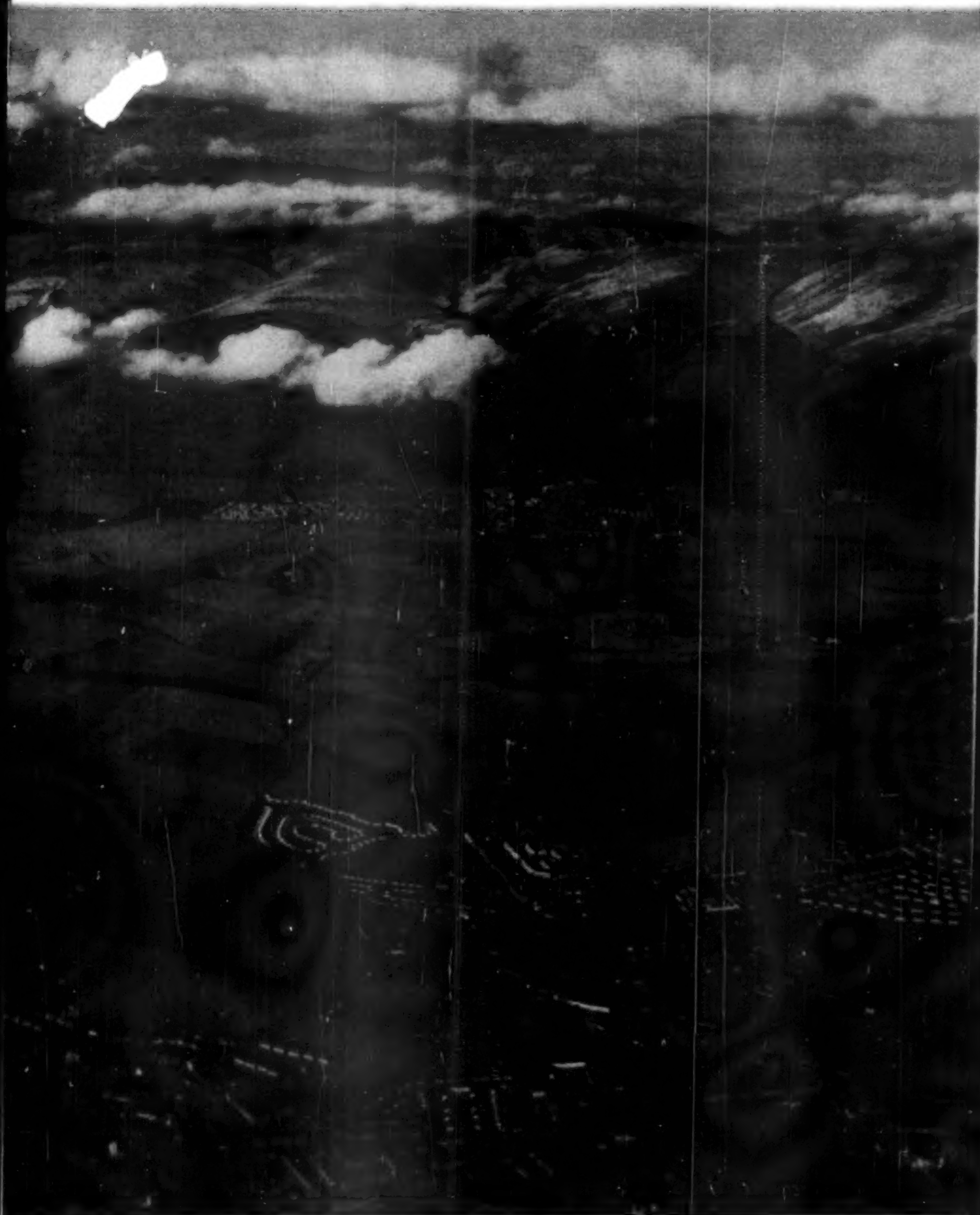
Pl. 3. Stirling Castle on volcanic plug (centre foreground) and the Ochil fault line scarp looking east; Abbey Craig (volcanic sill) with Wallace Monument (left centre). Carselands and meanders of Forth (centre) merging into Devon valley beyond; colliery right; hillfoot towns left.



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Pl. 4. The Ochil front and Devon valley viewed from the south. Ochil Main Surface cloud-capped. Incised valleys "hang" above the lowland and provide water power originally harnessed for the textile industries of hillfoot towns such as Alva (centre). Northern outskirts of Alloa in foreground.

aries. The Devon, however, was undoubtedly a much smaller stream, diminished by the loss of its headwaters, and responding to changes in base level more slowly. An equivalent of the Ochil Lower Surface may have developed on the less resistant strata covering the Plain of Kinross – the valley benches of the Kinross Ochils suggest that this was so – but only a relatively narrow valley can have represented this stage in Glen Devon.

The whole history of the present landscape of the Ochils and its bearing on that of a wider area is closely related to this contrast of stream size – of a small stream occupying a narrow drainage basin lying in part across resistant rocks, and two larger streams with wide catchment areas and courses crossing less resistant rocks on either side of the Ochil block. From this contrast follows the dismemberment of the early Devon and at the same time the preservation of evidence of stages in the landscape development which has elsewhere disappeared.

Although the Ochils are detached from other upland areas it is possible to attempt a correlation of the two major upland surfaces with those found in other areas. Thus the Ochil Main Surface may be represented in the higher parts of the Campsie Fells, although the summit level is here rather lower than in the Ochils. It may also correspond to the Grampian Lower Surface mapped by Fleet,[18] to which it bears some resemblance in form and in altitude. The Ochil Lower Surface may well have a counterpart in the extensive moorlands of the Cleish Hills, which have a similar range of altitude, and may be the Lowland representative of Fleet's Grampian Valley Benches. In the absence of evidence within the area permitting their dating, no reliable estimate can be made of the probable age of these surfaces.

Grateful acknowledgements are due to the University of Glasgow, for financial assistance with the fieldwork on which this account is based.

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THE SIGNIFICANCE OF WATER POWER IN INDUSTRIAL LOCATION

SOME PERTHSHIRE EXAMPLES

W. H. K. TURNER

PROBABLY one of the most impressive features of the last century and a half has been the way new and increased power resources have stimulated changes in industry. Distributions of industry have altered no less than their capacity for growth. Frequently, however, distributions established in relation to one source of power acquire another in its place without experiencing much locational change. Such would apply to much of our coalfield and urban patterns of industry, where electricity and oil in this century increasingly compete with coal and gas as sources of power and energy. In these instances, though new locational elements also are being contributed, most of the older distribution makes a simple adaptation to changing circumstances and needs. Adaptations of this kind become more difficult of achievement where the units of industry are remote from substantial centres of manufacture, population and trade. They are most difficult of all where, in addition to remoteness, the economic circumstances of the industries concerned no longer favour growth. It is of interest, therefore, to select for analysis some remnant from a contracting distribution such as this, whose localisation occurred in relation to a source of power generally long obsolete; and to consider what light its evolution and subsequent adaptation may throw upon principles of industrial location in general. It is for this reason that this study of surviving water-powered textile manufacturing and processing units in Perthshire has been made.

One of the distinguishing features of the Industrial Revolution was the application of power to machines on a larger scale than hitherto. This depended initially on the use of streams. A traditional support of industry thus acquired new and more impressive associations. A variety of industries had long made use of water-power, but on so small a scale, and showing characteristically so easy a dependence on local materials, that they had achieved without difficulty a wide dispersal. More selective influences made themselves felt as capital investments grew and systems of trade became more closely knit. New industrial growth was thus controlled increasingly by towns wherein merchant control and commercial activity were centred. Nowhere was this more in evidence than in Scotland in the eighteenth and early nineteenth centuries, when Glasgow and Dundee influenced so profoundly the respective regional distributions of cotton and linen manufacture. [1] The more interesting of the water-powered textile works surviving in Perthshire are remnants of these early distributions. Having withstood not only the early nineteenth century contraction to coalfield or large town, but also the later regional decline of cotton and linen working, they are especially notable. In addition, there is one wool textile works which continues to use water power.

These general features may be analysed further. The selection of river falls for relatively large-scale developments in the textile industry

occurred mostly in the period 1736-1836. It began when important linen bleachfields were established near Perth, along the Almond and Tay: two of the three surviving bleachfields, Huntingtowerfield and Stormontfield, continue to use water power. More spectacular were the cotton mills built when the Glasgow cotton industry expanded eastwards towards the end of the eighteenth century. The most notable of these, and the only survivors, are those at Deanston and Stanley, both dating from 1785 when Sir Richard Arkwright's patent for roller-spinning lapsed. Both owed their inception in part to him. [2] Deanston and Stanley mills came to be controlled by firms in Glasgow, and existed in the early nineteenth century as outliers to the industry there. Not long after the earliest cotton mills were built, water power was applied in Perthshire to flax-spinning, but most of the flax works were constructed in the period 1820-35. Whereas cotton working had spread from the west, flax and linen working, influenced by the progress of the industry in Dundee, made their greatest impact in eastern Perthshire. There were some developments in the valley of the Almond, but the most spectacular were those along the Ericht at Blairgowrie. Three survive out of the fourteen Blairgowrie mills that existed in the early nineteenth century; these show changes modelled on those that have taken place at Dundee, and now work jute and rayon staple as well as flax. Finally, stemming from an earlier tradition of workmanship, a scatter of small woollen mills emerged after *c*.1830. The making of "woolen cloths for common wear", and of carpet yarns for manufacturers at Stirling and elsewhere, [3] had been common Perthshire practices closely allied to native sheep farming. Not many of the nineteenth century mills that extended this tradition still exist. The most notable survivals are at Pitlochry, Aberfeldy, Auchterarder and Dunblane; but only at the last named, on the Allan Water, does water power for wool manufacture retain any significance. (Figure 1).

RIVER AND SITE

The developments that concern us took place within a relatively narrow strip of country on the accessible lowland margins of highland Perthshire. Seldom were the power sites further than ten miles from the geological fracture zone of the Highland Boundary. They were chosen where the rivers, having left high ground, force steep gradients through bordering lowland surfaces, and thus gather speed in their lower courses. The Teith, Almond, Ericht and Tay were especially notable; also significant was the Allan Water.

Some analysis of the relevant physical characteristics of these rivers suggests why they were attractive to the industrialists of the period, and serves also to indicate some of their deficiencies as power providers. The Almond and Ericht in many ways compare. They are typical mountain streams of much the same length, with relatively short, direct courses. Swift flowing, quick rising, violent in flood, they respond sharply to whatever seasonal changes in precipitation are experienced on the bare moorlands where they arise. The Tay and Teith, on the other hand, drain catchment areas which are larger and more diverse.

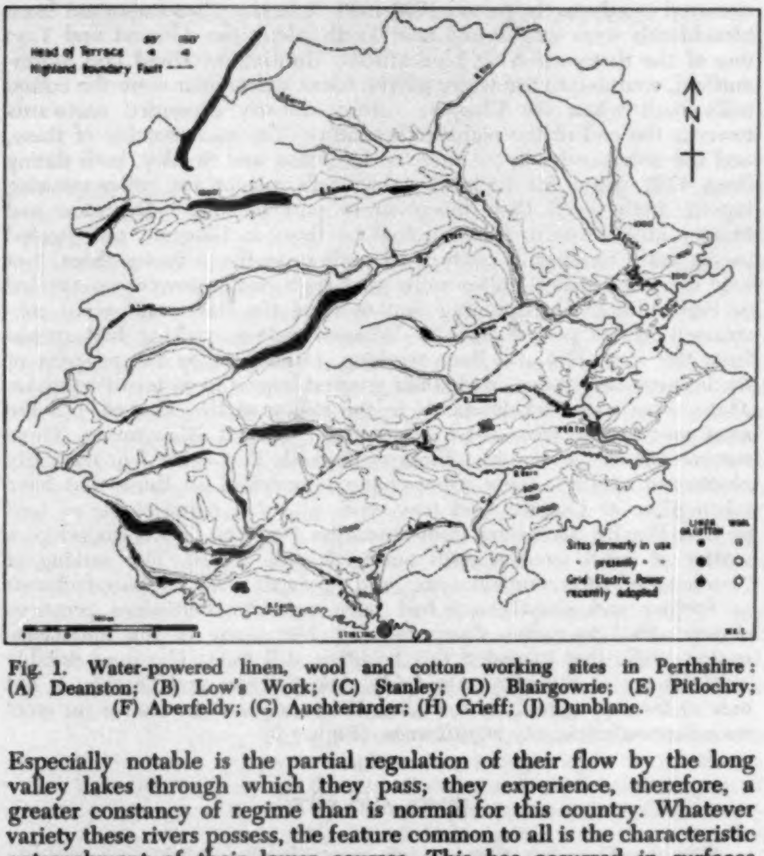

Fig. 1. Water-powered linen, wool and cotton working sites in Perthshire: (A) Deanston; (B) Low's Work; (C) Stanley; (D) Blairgowrie; (E) Pitlochry; (F) Aberfeldy; (G) Auchterarder; (H) Crieff; (J) Dunblane.

Especially notable is the partial regulation of their flow by the long valley lakes through which they pass; they experience, therefore, a greater constancy of regime than is normal for this country. Whatever variety these rivers possess, the feature common to all is the characteristic entrenchment of their lower courses. This has occurred in surfaces developed at levels of 200-250 feet and 400-450 feet. The first of these undulates considerably, but in several areas ends abruptly where a terrace edge at *c.* 200 feet O.D. marks a former sea margin. The lower Teith, Tay and Almond develop speed where they cut into this surface; and their gradients steepen again as the rivers trench into the 100 - foot and 50 - foot terraces which occur successively downstream. Similar incisions have been made by the Ericht and Allan Water, but within the 400 to 450 - foot surface. In most instances notable gorges have been cut, sometimes with cliffs rising a sheer 200 feet above stream level. Sections such as these, through providing a maximum of power at points near to settled lowland populations, were those to which industry was most attracted.

A general examination of mill and bleachfield sites suggests that the industrialists who chose them made fairly precise evaluations of the physical advantages the rivers offered. Thus, there were notable developments where the Tay, Teith and Almond cut into the 100 - foot

and 50 - foot terraces. The present weir for Deanston Mill stands exactly at the head of the 100 - foot terrace, and provides a fall of 33 feet for the mill downstream. [4] (Fig. 2). On the Tay there were three weirs within a stretch of a mile-and-a-half, just above and below the riverine peninsula at Stanley. (Fig. 3). On the Almond, in a comparable position, there is a spectacular diversion from the weir at Low's Work along the Town's Lade to Perth. (Fig. 4). Along the Allan Water, Springbank Mill was built where the river begins to bite into the 200 - foot surface, and Ashfield Printfield where its entrenched course begins. (Fig. 1). There are many other similar instances, but these are enough to show clearly the way in which steepened valley gradients provided attractive falls for industry in an earlier period.

The presence of meanders often increased the attractions of rejuvenated river courses. Some of the meanders of the Almond, for instance, permitted relatively easy and powerful diversions of water to be made; while Westfield and Craig mills on the Ericht, the highest of those within the gorge, were placed where the river sweeps in a broad curve before the last straight stretch of its mountain tract. (Fig. 5). Most spectacular of all, however, is the meander at Stanley; and the human response that it has evoked goes far to match in impressiveness the physical quality of the site. Here the Tay, deeply incised in the 200-250 foot level, loops sharply to form a peninsula which over-tops the river by some 150 feet. The mills stand on the south side of the peninsula, the weir that serves them spans the river to the north, while power is brought by a lade tunnelled deep in the high ridge of the meander core. By this short cut the natural fall of the Tay is more than trebled in what is probably the most powerful section of its lower course. (Fig. 3).

Most of the power-using sites formed simple lateral patterns along the streams, their location influenced by physical considerations such as those already instanced. In a sense, much of the industrial dispersal thus achieved was prompted by increased competition for power resources. Along the Almond, for example, industrialists only began to choose riverside sites for textile working after first exhausting the possibilities offered by Perth's Town Lade. [5] Dispersal of this kind resolved competition between industrialists by the simple choice of a succession of sites, none of whose resources were sufficiently outstanding to claim the interest of other power-users. Sometimes, however, one finds competition taking place for the same resources; and instead of normal lateral distributions one has paired arrangements, in which works occupy similar positions on each side of the river and derive power from the same stretch. An unformalised arrangement of this kind occurs with the two bleachfields that face each other across the Tay. (Fig. 1). In both cases haughs provided level ground for the one-time grassing of the cloths, terraces gave abrupt falls close to the works, and long two-and-a-half-mile lades brought power from the great meander at Stanley. More spectacular examples of pairing, however, took place where power resources were sufficiently large to invite the siting of industry on both banks, but not large enough for there to be any sharing of these resources without formal arrangements. A development of this kind took place within the Ericht gorge, on the steep,

difficult slopes just above the Linn of Keith. Here were built Blairgowrie's 'bank' mills. Keithbank was paired with Oakbank, Bramblebank with Ashbank. Serving each pair was a common weir, built jointly by mill-owners according to agreement. The manner of lade construction was agreed upon similary, regulating the height of fall and the openings into the lade on each side of the Ericht. Between its confluence with the Lornty and the Keith the power resources of the river were thus divided equally between users on both banks, and formal contracts supported the parallel arrangements that arose. (Fig. 5).

If one views these distributions as a whole, it is clear that there are comparisons to be made between the Almond and Ericht on the one hand, and the Tay and Teith on the other. The first two supported a considerable extension of industry; and in each case the distinction can be made between mill sites in the gorge and those on the long lade below. Such distributions are interesting in showing differences related to the amount of fall available. Thus, in the case of the Ericht, the gorge sites occur above the Linn of Keith – a rocky chasm cut in sandstone at the head of the 200 - foot terrace – where there were eight mills within half-a-mile. Below the Linn the five mills along the lade from Blairgowrie's old ford were dispersed over a distance of nearly three miles. (Fig. 5). The Tay and Teith, on the other hand, were used at only a few select points, notably at Deanston and at the great river bend at Stanley. The power associations of this last named stretch were the most impressive in the county. The great sweep of the Tay, below the point where it breaches the Permo-Carboniferous dyke at Campsie Linn, [6] and above the upper limit of its tidal section at Scone, was clearly the most attractive on the whole river. These qualities gain in significance when it is realised that of the rivers in Britain the volume of the Tay is largest of all.

Finally, one should emphasize that the value of many of the sites considered had already been appreciated before the Industrial Revolution made its impact. Of those chosen for the various textile works probably more were in use for water-powered milling of one sort or another than were not. Seldom was there involved the selection of a site wholly undeveloped previously, and even where this did occur some contributory feature of past use, such as the presence of a lade to serve a mill elsewhere, often influenced the choices made. Clearly in a country accustomed to the use of water power for centuries, and in which this use was quite dispersed, the most obvious falls along river and stream had already been seized. What was often involved therefore, was a complete reassessment of resources whose development had been sufficiently discriminating in the past to draw attention to sites to which these altogether larger and more potent forms of industry might be attracted. (Fig. 6).

There are a number of instances that support this conclusion. Perhaps the most obvious was the growth of industry along the Town's Lade of Perth. The Lade, constructed originally to provide power for the medieval corn mills at Perth, subsequently supported much industrial dispersal away from the town. Also there was the adoption of particular sites where milling was already practised, and small rural mills were converted and enlarged for the new industry. For example, at Ruthven-

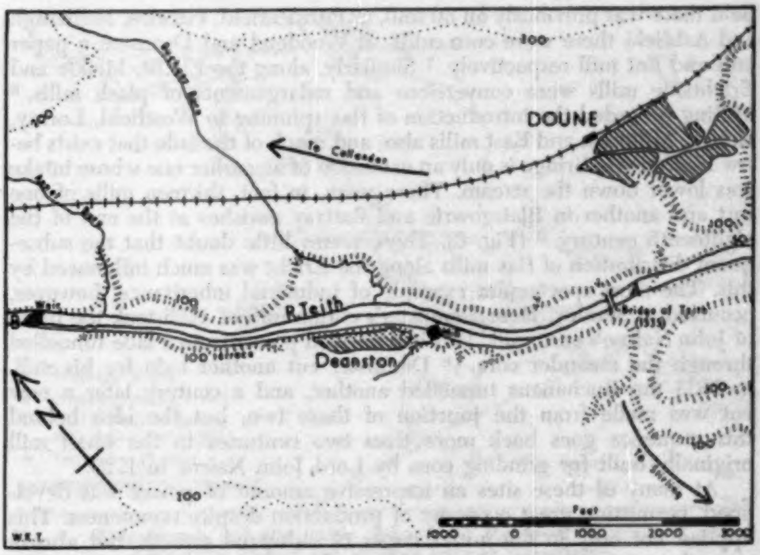

Fig. 2. The location of Deanston Mill; A,B-Heads of 50-foot and 100-foot terraces respectively.

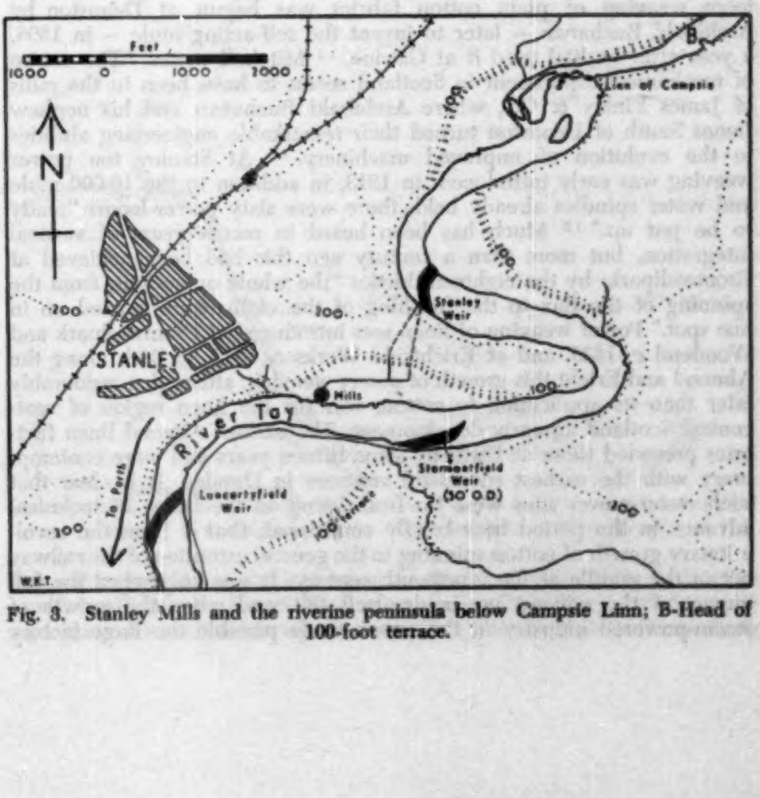

Fig. 3. Stanley Mills and the riverine peninsula below Campsie Linn; B-Head of 100-foot terrace.

field there was previously an oil mill, at Pitcairnfield, Pitcairn, Millhaugh and Ashfield there were corn mills, at Woodend and Deanston a paper mill and lint mill respectively. [7] Similarly, along the Ericht, Meikle and Erichtside mills were conversions and enlargements of plash mills. [8] Milling preceded the introduction of flax spinning to Westfield, Lornty, Haugh, Milltown and East mills also; and much of the lade that exists below Blairgowrie Bridge is only an extension of an earlier one whose intake was lower down the stream. There were, in fact, thirteen mills of one sort and another in Blairgowrie and Rattray parishes at the end of the eighteenth century. [9] (Fig. 6). There seems little doubt that the subsequent distribution of flax mills along the Ericht was much influenced by this. The most spectacular example of industrial inheritance, however, occurred at Stanley. Here Dempster's cotton mill of 1785 took the place of John Nairne's corn mill. This had derived power from a lade tunnelled through the meander core. [10] Dempster cut another lade for his mill, in 1823 the Buchanans tunnelled another, and a century later a new cut was made from the junction of these two; but the idea behind this sequence goes back more than two centuries to the small mill originally built for grinding corn by Lord John Nairne in 1729.

At many of these sites an impressive amount of power was developed, permitting great economy of production despite remoteness. This applied not only in the initial stages of industrial growth, but also in several cases well after steam-power industry had established itself in the towns. At each of the major stages of technological advance early developments took place at many of the sites considered. Thus, power-loom weaving of plain cotton fabrics was begun at Deanston by Archibald Buchanan – later to invent the self-acting mule – in 1808, a year after he had tried it at Catrine. [11] Mitchell writes, "The centre of mechanical experiment in Scotland seems to have been in the mills of James Finlay & Co., where Archibald Buchanan and his nephew James Smith of Deanston turned their remarkable engineering abilities to the evolution of improved machinery. [11] At Stanley too power weaving was early introduced: in 1813, in addition to the 16,000 mule and water spindles already held, there were sixty power-looms "ready to be put up." [12] Much has been heard in recent years of vertical integration, but more than a century ago this had been achieved at Cromwellpark: by the eighteen-thirties "the whole operations, from the spinning of the flax to the finishing of the cloth, were carried on in one spot." Power weaving of linen was introduced at Cromwellpark and Woodend *c.* 1835, and at Erichtside Works *c.* 1843. [13] Both along the Almond and Ericht this growth of power weaving, although considerably later than its application to cotton, was for the linen region of east-central Scotland an early development. The earliest Almond linen factories preceded those at Perth by some fifteen years and were contemporary with the earliest successful ventures in Dundee. It is clear that such water-power sites were far from being on the fringe of technical advance in the period here briefly considered, that is from the revolutionary growth of cotton spinning to the general extension of the railway net in the middle of the nineteenth century. It was only when the full impact of the railway age made itself felt, and when the growth of steam-powered industry in the towns made possible the large factory

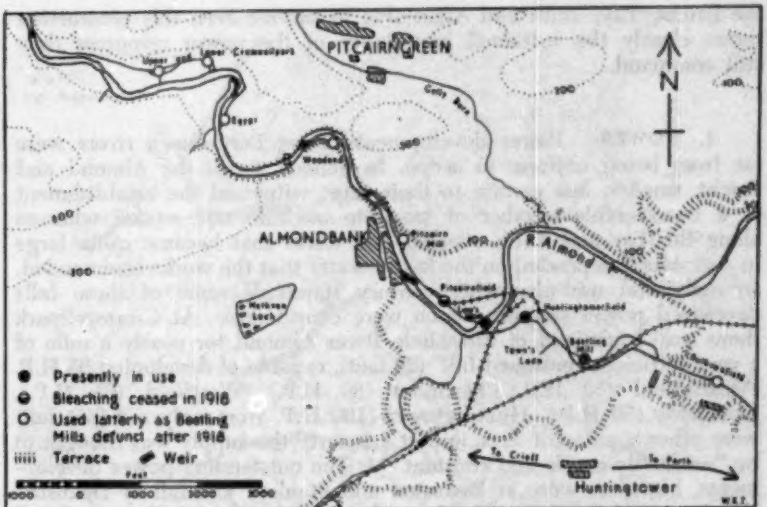

Fig. 4. Water-power and the textile industry of the lower Almond; A and B Heads of 50-foot and 100-foot terraces respectively.

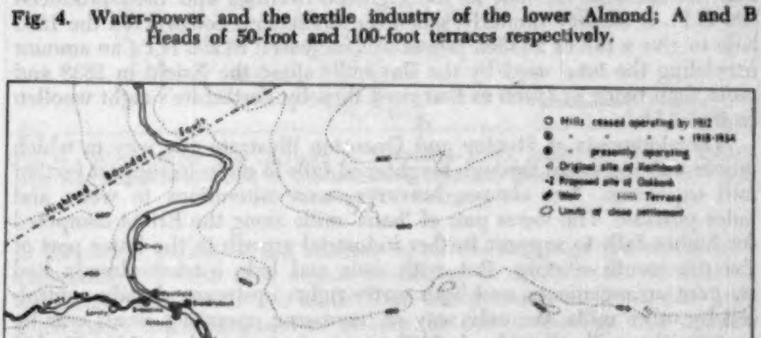

Fig. 5. Water-power and the textile industry at Blairgowrie.

expansions typical of the latter part of the nineteenth century, that the rural textile works found themselves increasingly at a disadvantage and generally declined in significance. That there have been those along

the Ericht, Tay, Teith and Allan able to survive even this contraction shows clearly the sustained importance of the power resources they still command.

1. POWER: Power developments along Perthshire's rivers were far from being uniform in scope. In general terms the Almond and Ericht, smaller, less certain in their flow, witnessed the establishment of a considerable number of small to medium size works; whereas along the Tay and Teith evolved few works that became quite large in size. Much depended on the fall of water that the works commanded. By early and mid-nineteenth century standards some of these falls developed power supplies which were considerable. At Cromwellpark there was "command of the whole River Almond for nearly a mile of a very sufficient continued fall" (20 feet), capable of developing 65 H.P. Pitcairnfield (50 H.P.), Stormont (80 H.P.), Westfield (65 H.P.), Erichtside (50 H.P.), Huntingtower (100 H.P. from only a 6-foot fall) were other significant sites, and at Luncarty the supply was thought to be "unusually ample and constant" [14]. The outstanding power developments, however, were at Deanston and Stanley. The fall at Deanston was increased to 33 feet in the eighteen-twenties and then produced 306 H.P. At Stanley similarly, when the Buchanans constructed the 1823 lade to give a fall of 16 feet, power was increased to 202 H.P., an amount exceeding the total used by the flax mills along the Ericht in 1838 and more than twice as much as that used then by Perthshire's eight woollen factories [15].

Developments at Stanley and Deanston illustrate one way in which power was increased through heightened falls in order to support further mill expansion. Not always, however, were alterations to weirs and lades possible. The lower pair of 'bank' mills along the Ericht competed for higher falls to support further industrial growth in the latter part of the nineteenth century. But with weir and lade intakes already tied by joint arrangements, and with water rights upstream already controlled by other mills, the only way of increasing operating heads was by moving the mills. Keithbank Mill was in fact moved, in 1864-65, 100 yards downstream to its present site. In competition, the Grimonds projected a new site for their mill at Oakbank; and a lade was driven through the Linn, by-passing the falls, to a site where it was intended to take advantage of the steepened gradient of the Ericht in its cataract through The Keith (Fig. 5). But the scheme fell through. All that remains now is the empty, rock-hewn lade that was never used, and a pile of boulders that stands incongruously above the river's torrent course.

Seasonal fluctuations of river regime played an important part in determining the ultimate value of water power at any particular point. Along the Tay and Teith, through the reserves provided in the lakes that occupy their upper valley reaches, such fluctuations are much less than along the Almond and Ericht, though yet are sufficiently pronounced to make their influence felt. Of Deanston Mill it was said, "The steadiness of the Teith renders the command of water extremely uniform, and the loss of a few hours per day for a week or fortnight

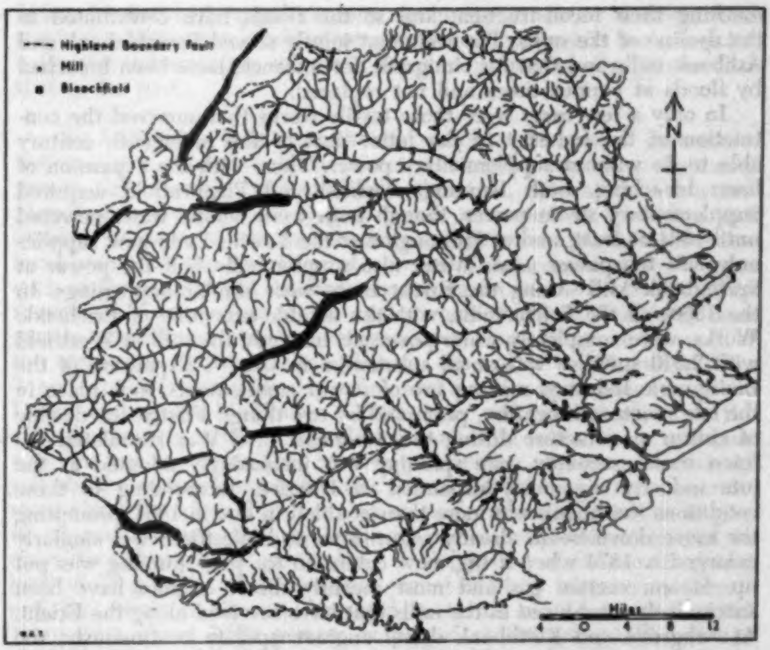

Fig. 6. Water-power and industry in Perthshire 1783; based on James Stobie's map *The Counties of Perth & Clackmannan*, 1783. (A) Deanston; (B) Low's Work; (C) Stanley; (D) Blairgowrie.

in the driest period of the summer is all the stoppage the works ever experience [16]." The falls varied according to river level. At Stanley, for instance, the 1921 cut made from the junction of Dempster's and Buchanan's lades increased to 24 feet the fall to the Tay, but summer low water may reduce this to 20 feet and winter high water to 17 feet. So great the catchment area of the Tay, so bare the steep slopes that drain to it, that high precipitation in winter causes river spates of 11 feet or more, checking the outfall of the lades and reducing, when the river itself is most powerful, the amount of power actually developed. Winter frosts too diminish drainage, lessen river flow, and reduce the power produced. Along the Ericht ice forms on the calm, slow-moving water above the weirs, often spreading as a sheet in mid-winter and lessening the entry of water to the lades. More catastrophic were the floods along both Almond and Ericht, occasionally sweeping away altogether the weirs across their paths. Both are fast-rising mountain streams, the Almond often coming down in floods with four-foot perpendicular breasts, the Ericht too noted for "the variableness of its size.... In winter it comes down in terrible spate, while in summer it is nearly dry [17]". Some of the wooden weirs characteristic of the Ericht have been swept away and not always have they been replaced, the costs of rebuilding in circumstances perhaps unpropitious economically not

meriting their reconstruction; and so the floods have contributed to the decline of the mills. The weir that jointly served Bramblebank and Ashbank mills and that for Craigmill, for instance, have been breached by floods at various times and not replaced.

In only a few cases were those textile works that survived the contraction of the industry in the latter part of the nineteenth century able to do without supplementary power. Thus, with the expansion of linen bleaching, both Huntingtowerfield and Pitcairnfield acquired supplementary steam power, though both were wholly water-powered until 1864 at least; and at Huntingtower the Town's Lade now supplies only half the power used. Water also supplies only half the power at Springbank Mill. Along the Ericht there were similar happenings. In the 1860s all the Ericht mills, with the notable exception of Erichtside Works, were completely water-powered; but only the mill at Westfield with 2,540 spindles was at all substantial in size [18]. Expansion of the Blairgowrie industry, making use of power supplements, took place in the late nineteenth century, prompted by two things. Firstly, the decline of cotton manufacture during the American Civil War stimulated the linen trade; secondly, jute spinning was increasingly adopted as the jute industry vigorously expanded in Dundee. Responding to these conditions Keithbank was more than doubled in size in 1864, prompting the move downstream already referred to; and Westfield was similarly enlarged *c.* 1874 when a big, new extension for jute spinning was put up. Steam, suction gas and most recently diesel engines have been successively introduced in the mills that have survived along the Ericht. At Ashgrove and Keithbank diesel engines operate continuously, the water power now, due to further enlargements made since 1939, being insufficient to drive the whole of either mill at any time. The size of these mills, quite large and imposing, contrasts vividly with the small derelict mill at Lornty, to which no substantial addition was made in the whole period of its existence. Lornty Mill suggests what all the Ericht mills might have looked like when first they were built.

At those sites where stream flow is the sole or major source of power water-turbine and individual hydro-electric plants have replaced the old water-wheels. The four water-wheels (diameter 36.5 feet) installed at Deanston, 1830-33, continued to power the mill until 1949, when the works was reconstructed and water-driven turbines coupled to alternators were installed. A similar change took place at Stanley in 1921, and at Stormontfield and Westfield in 1950 [19]. Only the Tay and Teith have provided a really satisfactory basis for the sustained use of water power. Elsewhere vagaries of stream flow and inadequacy of volume or fall have led to the acceptance of power supplements to sustain the growth of works whose expansion has been a condition of survival; and where this has happened inevitably there has been a reduction in the economies of working. At Stanley and Stormontfield the works are still wholly water-powered. Deanston was too, until 1939 when a diesel engine was installed to augment water power during low water or flood conditions. The mill at Deanston, reconstructed and modernised in recent years, is much smaller than the old works, with only 260 automatic looms compared with the 14,184 throstle spindles, 12,384 mule spindles and 302 power looms held over a century

before [20]; but high speed modern machinery, its ratios different from those of earlier plant, working intensively on double-shift basis, requires a degree and certainty of power supplies proportionally greater than that in the past.

2. LABOUR: It is clear that for much of the period here under review there existed a fairly direct relationship between degree of power, size of works, and implicitly, therefore, amount of labour employed. In particular, the largest power sites such as Deanston and Stanley, where were attracted the largest investments of capital, became focal points for the formation of new industrial communities. Villages such as these stood out distinctively among an otherwise normal distribution of rural settlement in areas whose interests had long been mainly agricultural. Stanley emerged as a new village at the end of the eighteenth century, followed some time after by Deanston (Figs 3 and 4). Deanston Mill depended first on the expansion of nearby Doune and on Mr Murdoch's "Cotton Row" (48 houses) adjoining the mill, the growth of the village dating from 1811 when the original six acre feu was enlarged. That Stanley grew earlier and more extensively reflects the remoteness of its mills from established centres of settlement along the lower Tay. Rural in setting, and in the case of Stanley in appearance too, these mill villages were completely industrial in character. This applied particularly in the period of their earliest and most virile growth, when the employment of child labour was normal and the whole family was engaged in textile manufacture. In 1839 there were about 1,000 persons employed at Deanston Mill and 913 at Stanley[21], nearly all of whom came from the mill villages and from neighbouring, old-established settlements such as Doune.

Contrasting with the cotton mills were the early nineteenth century flax and wool mills. Typically they were much smaller. The woollen mills, smallest of all, employed in 1838 for the whole of Perthshire only 227 people and so stimulated little settlement growth. They had most significance in the larger population centres like Crieff, Dunblane, Pitlochry, Aberfeldy; while small mills like those at Netherton, Camserney, Kilmahog and Meikle Trochry inspired little change in population patterns. The flax mills were more important, but in 1839 all the Blairgowrie mills employed only 463. Even in 1864, when the number employed had risen to 1,650, the largest of those then depending wholly on water power was Westfield with only 160 [22]. The flax mills, therefore, did not inspire contributions to the rural settlement of Perthshire which compared with those prompted by cotton spinning. Certainly, the mills along the Ericht were fairly well served from Blairgowrie itself, particularly Erichtside the largest of them. But their linear extension upstream and downstream led to the construction of small, supporting house-clusters for key workers. Thus, at Oakbank a small row of two-storey houses and some derelict cottages stand along the road above the mill, and similar industrial clusters are evident elsewhere. These house groupings were sometimes sufficiently large and isolated to give rise to minor, industrial communities which were outliers of Blairgowrie itself.

Along the Tay and Almond there were comparable developments.

Older settlements such as Methven were stimulated and enlarged; and entirely new industrial communities evolved at Almondbank, Pitcairngreen, Huntingtower, Ruthven, Luncarty and Stormont. The modern road and bus serves most of these adequately, the people themselves conscious that they belong to a framework of relationships extending beyond the bounds of the settlements in which they live. But there is something disjunctive and anachronistic about the continued tenancy of the old house clusters beside the derelict mills of the Ericht. Similarly, the small bleaching community on the banks of the Tay at Stormontfield, secluded, remote, served directly only by a bus each Saturday to Perth, evokes a sense of inappropriateness at the social legacy conferred here by the sporadic industrial growth that took place along the rivers more than a century and a half ago.

In most cases there has been a marked reduction in the numbers employed at the textile works referred to. This has been due to the regional decline of textile manufacture, and to the increasing use of machinery and processes that require less labour to tend them. Whereas in the last century printfields, bleachfields, mills and factories attracted labour and inspired much settlement growth, in this century the development of road transport has conspired with the reduced circumstances of the textile industry to create in some instances difficulties of labour supply. Settlements such as Stanley that evolved as industrial communities are no longer exclusively so. The traditional agricultural background has reasserted itself, and the pull of the nearby town has made its influence increasingly felt on the descendants of the mill workers of the past. These features are seen most clearly at Stanley and Deanston. At Stanley, although the village still supplies most of the labour of the mills, many of the villagers find employment in Perth or on local farms [23]; and the mills themselves have been forced to seek labour elsewhere, casting a net over the settlements within a nine-mile radius and bringing in labour daily from Perth, Coupar Angus, Blairgowrie and Dunkeld. Deanston Mill, at a distance from Stirling similar to that of Stanley from Perth and feeling keenly the competition for labour resulting from the new, industrial developments there, has its labour problems too, despite the fact that it now employs only 220 people compared with 1,000 in the past. Some 55-60 per cent of the workers of Deanston Mill come from Deanston and Doune, the remainder brought in from Stirling and Callander by special buses or with fares paid. It is with inducements such as these that the out-of-the-way rural mills now compete for labour within the growing hinterlands of the towns.

Company houses are another form of inducement, adopted from the beginning to attract a fixed, dependable, local labour supply. The majority of the workers at Huntingtowerfield are housed thus, and for the small bleaching community at Stormontfield the tenancies form part of the workers' wages. The reduced stature of the cotton and linen industries in the county, the movement away from settlements whose growth was inspired by the emergence of these industries, the pull of the modern town on the labour force of its region, have all conspired to make increasingly difficult the support of industrial units in rural locations such as those instanced here.

3. TRANSPORT AND COMMUNICATIONS: Most of the works referred to depended originally on pack-horse and cart transport along roads linking them with the major commercial centres. These communication lines were much shorter for the units of the linen industry whose links were with Dundee than for the cotton mills that were distant outliers of Glasgow. Deanston and Stanley are about thirty-five and seventy miles respectively by road from Glasgow, Blairgowrie, only eighteen miles from Dundee. But in the early nineteenth-century heyday of the Glasgow cotton region such differences mattered little. It was only with the contraction of that industry that the outlying mills began to feel more acutely the factor of distance. Probably as a consequence of this Stanley Mills, faced with the contraction of cotton manufacture first in Perth and then in Glasgow, finally became associated with Dundee and depended for a time on making cotton selvedge and sewing twine for the jute and linen works in the Dundee textile province, only more recently developing the manufacture of cotton belting and tapes for which now it is best known [24]. Deanston, on the other hand, much nearer to Glasgow, has retained its early associations and the character of its early productions.

When the railway net was established, its adjustment to the settlement pattern, and its use of major valleyways along whose rivers water-powered industry was located, increased the accessibility of the various units of industry along the highland edge. Thus Luncarty, Stanley, Ruthven, Almondbank, Doune, Dunblane and Blairgowrie all came to be served, movement of goods by rail from these places focussing on the railway nodes of Stirling and Perth. It is certain that in the latter part of last century the railways made important contributions to the movement of goods to and from such works, facilitating an extension and multiplication of contacts and increasing speed of service. At Huntingtower, for instance, where the bleaching of Irish damasks had considerable importance at one time, the rail link with Almondbank supported this trade. Goods sent from Belfast were railed from Glasgow to Almondbank and from there directly into the works; in 1911 this rail link was extended to Pitcairnfield nearby (Fig. 4). For the bleachfields, concerned with the receipt and despatch of piece goods in quantity from a multiplicity of sources, such considerations bulked larger than for the spinning and weaving works deriving their supplies mainly from the ports; and there is little doubt that the development of Perth as a major focus for a number of different rail routes increased greatly its value as a communication centre, and thus conferred a larger measure of accessibility for the bleachfields nearby. Perth's centralising influence on the distribution of industry along the Almond and Tay was therefore considerable. As there was a lesser development of industry along the Teith and Allan, and because of the relative proximity of Glasgow, Stirling had much less significance in these respects. Blairgowrie, almost equidistant from Dundee and Perth, divided its contacts unequally between both, its industry depending more heavily on the flax and jute supplies and the weekly yarn market of Dundee than on the convenient transport facilities that Perth provides.

With the growth of rail communication transport by road, and by coaster from Perth, at first sharply declined, but conditions changed

again in this century with the enormous growth of road traffic and the recent contraction of rail services. The rural mills and bleachfields now exist in conditions similar to those in which they were established, primarily dependent on the road and more directly accessible than they were formerly. Accessibility, however, is one thing, costs of transport another. The decline of Glasgow as a cotton centre meant that outlying units of the cotton industry, as at Deanston and Stanley, found themselves especially vulnerable to increased costs through higher transport charges as links were established increasingly with Lancashire. This has applied also to the bleachfields, which, with the decline of linen bleaching since the First World War, have depended more and more on cotton and rayon goods sent from Lancashire for bleaching and dyeing. It is the great Lancashire trade which is now the main support of Perthshire's remaining bleachfields. Lorries go daily from Huntingtower and Stormontfield, for instance, to Manchester, with the guarantee of quick service and delivery. Goods loaded at the bleachfields at night are delivered to the customer's warehouse next morning. In addition, there are routine weekly lorry services around the textile factories of the local region; and one of the two bleaching firms brings in its coal by lorry direct from the pit at Keltie, Fife. Likewise, Stanley Mills derives its raw cotton by road each week from Liverpool. While the modern integration of Deanston Mill with the larger works at Catrine in Ayrshire depends similarly on the frequent, repetitive lorrying of yarn and cloth over a distance of some seventy-two miles [25]. About one-third of Deanston's production of cotton sheets, pillowcases and towels is for shipping companies, much of it sent as far afield as Southampton. With the woollen mills also, imported wools and Yorkshire yarns have long taken the place of the original alliance with native sheep-rearing, and communication lines have been similarly extended. It is clear, therefore, that in many cases the distances involved in transporting supplies and goods for marketing are considerable, and transport costs figure as a large item; but whether these are more than for many other branches of industry in Scotland in problematical.

CONCLUSION

In the eighteenth and early nineteenth centuries attractive river falls, marginal to highland and lowland alike, offered major advantages to industrialists in Perthshire. Providing a sufficiency of power near to established centres of settlement and trade, they supported a growth of industry whose maximum distribution reflected clearly the expansion of urban interests. The Almond and Ericht distributions thus arose, not because of any special physical advantages, though these were considerable, but through the extension of merchant interests from the towns. Such interests began to contract as urban power resources grew; and contracted further when regional textile manufacture declined. Where works survive, their proximity to secondary townships once significant for textile manufacture is accompanied by few of the advantages originally held, because so much of this significance has been lost. Their associations have been extended therefore, to the primary urban centres upon which regional distributions of industry ultimately

devolve. The remoteness of such industries at the present time is thus greater than that suggested by an examination of settlement and communication patterns alone. The Ericht mills and those at Stanley are to be regarded as regional outliers of the industry in Dundee, and no longer industrial dependencies of Blairgowrie and Perth. A similar and even more extended relationship exists between Perth's bleachfields and urban manufacturing centres in Lancashire. Only Deanston Mill, whose associations have been always with Glasgow, seems not to have experienced comparable change.

Much of the quality of remoteness, so characteristic of these water-powered units, has been conferred by the decline of regional industry. The survivors are few; the sense of anachronism that they survive at all is thus increased. All but three of the fourteen flax-spinning mills that evolved along the Ericht, for example, now lie derelict or converted to some other use. Remoteness has been a feature since the growth of power industry in the towns There is some difficulty, however, in determining the extent to which it subsequently created special disadvantages for rural industry. The difficulty exists because many of the mills were closed at times when urban industrial patterns also were contracting, in response to similar hazards of trade. Clearly, however, the small works, limited in size by the falls on which they depend, unable to expand save by the use of power supplements, would be those most susceptible to decline. But so much depends on the vigour and intention of management that seldom can one discern any tendency which has general application. It is easier to point to factors making for success than to those which result in failure. The most noteworthy of these is adaptability. Hence the continued interest in the larger, more accessible falls, where expansion and modernisation under vigorous management has provided worth-while economic rewards. No more notable examples of hitherto successful adaptations could be found than Deanston and Stanley mills, owned respectively by Glasgow and Dundee companies famed for their diversity and enterprise. Neither mill was profitable in its early years. Only with the extended use of power resources and the spectacular enlargements of the 1820-30 period, did they become remunerative. Similarly, the re-equipment that took place at Deanston in 1849, and its recent reconstruction as a weaving factory, provide striking instances of the sort of vital contribution vigorous control may make to successful survival. The adoption of automatic weaving and of high-speed spinning are similar adjustments. In all such cases adaptations have been prompted by the need to match the progress of industry in the towns. Only thus may the original advantage of cheap power be sustained. Social considerations have played their part too. Of the recent history of Catrine and Deanston James Finlay and Co. have said, "Moved at least as much by a sense of social obligation as by commercial calculation, it was decided to keep the mills open and to make steadily improvements in equipment. . . . it was not the profit motive that kept Catrine and Deanston going; it was the acceptance of a social responsibility, the acknowledgement of a social trust." The decision to rebuild Deanston following reconstruction at Catrine, when the opportunity existed for concentrating all production there, certainly seems to bear this out.

Times of economic stress discover weaknesses in any industrial distribution which lead to contraction whether industry is rural or urban in location. The least productive mills, with reserves of capital insufficiently large to tide them over a difficult period, are most susceptible to decline; but any firm might prove vulnerable, depending on some quirk of trade, or lack of further interest, or death among its principals. Where industry is in decline chance thus plays a notable part in deciding the extent to which old distributions contribute something of their original pattern to posterity, particularly where the establishments are fairly small. But where the unit of production, the industrial community, and the employing organisation are greater then the possibility of survival increases. In the case of water-powered industry this reflects on the physical basis of industrial growth. The tendency is for largest power sites to exert an attraction in proportion to the potentialities of their falls. Survival, then, ultimately provides a measure of the wisdom shown by the industrialists of the eighteenth and early nineteenth centuries who chose these sites. But in their choice more was involved than a simple appraisal of physical resource. Several sites had supported previously water-powered industry. Patterns of prior use influenced the assessments of the period, and contributed to the regional succession of industrial growth. Some of the surviving water-powered works thus extend not only a long tradition of power development, but carry on the significance of particular sites. For centuries, during the changing human geography of Perthshire, the rivers of the county have provided for industry an inexhaustible store.

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[1] Turner, W. H. K. The Textile Industry of Perth and District. *The Institute of British Geographers. Transactions and Papers*, 1957. No. 23. pp.123-140.

[2] Deanston Mill was built by John and Archibald Buchanan. John was a great friend of Arkwright, and his first agent in Scotland; Archibald was once an apprentice to Arkwright at his works in Cromford. Stewart, George. *Curiosities of Glasgow Citizenship*. Glasgow, 1881, p.181.

[3] *Old Statistical Account*. Vol. 5, p.62; Vol. 11, p.604.

[4] The fall was increased from 13 feet to 33 feet in 1826.

[5] The first mill site along the river, that at Cromwellpark, was set up five years after the last development along the Lade.

[6] This is the most resistant of several dykes through which the Tay has cut. It stands like a broken wall, and deflects in the river's course. The Linn itself is a 10-foot wide chasm, partly river-worn and partly blasted in the rock.

[7] Stobie, James. Map of Perth and Clackmannan, 1783. *New Statistical Account*. Vol. 10, pp.154, 1035.

[8] These were flax dressing mills established not long before flax-spinning by power came to Blairgowrie. Thus, Thomas Whitson of Parkhill, and Janet and Margaret Rattray of Craighall, received grants of £40 in 1786 for building plash mills along the Ericht; Minutes of the Board of Trustees for Fisheries, Manufactures and Improvements in Scotland, 20 February 1786.

[9] *Old Statistical Account* Vol. 17, p.198; Vol. 4, p.149.

[10] *New Statistical Account* Vol. 10, p.440.

[11] Mitchell, G. M. The English and Scottish Cotton Industries. *The Scottish Historical Review*. Vol. 22, 1924-25, p.108.
[12] *Perth Courier*, 10 June 1813.
[13] *Ibid.*, 9 February 1837; *New Statistical Account* Vol. 10, pp.190, 154.
[14] *Ibid*, 5 March 1812, 24 August 1815, 9 February 1837, 30 December 1858.
[15] *House of Commons Return*, 7 August 1838. *Accounts and Papers*, Vol. 42, 1839.
[16] *New Statistical Account*, Vol. 10, p.1235.
[17] Macdonald, J. A. R. *History of Blairgowrie*. Blairgowrie, 1899, p.185.
[18] Warden, A. J. *The Linen Trade, Ancient and Modern*. London, 1864, p.654.
[19] The mill at Westfield was burned in 1934, but the fall (the most powerful on the Ericht) is now used to provide hydro-electric power for Bramblebank Mill downstream.
[20] This was the machinery held in 1844. See *James Finlay and Company Limited, Manufacturers and East India Merchants 1750-1950*. Glasgow, 1951, p.72.
[21] *House of Commons Return*, 20 February 1839. pp.65, 68.
[22] Warden, A. J. *Op.cit.*, p.654.
[23] I am indebted to Miss Elizabeth Craig for this information, which appears in an unpublished dissertation entitled "The History of the Cotton Industry in Scotland".
[24] *Ibid.*
[25] In 1948 Deanston Mill was re-constituted as a weaving factory, equipped then with automatic looms, and integrated with the spinning, weaving and finishing works at Catrine.

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THE CHARTING OF THE SCOTTISH COASTS

A. H. W. Robinson

The coastline and inshore waters of Scotland have long presented a challenge to the marine surveyor. The west coast, in particular, with its penetrating inlets and intricate system of channels between the islands was the first to receive serious attention, as a result of the continuous losses of shipping arising from the lack of accurate charts. Parts of the east coast, particularly the shoaler waters towards the head of the firths, were none the less dangerous but it was not until the pressure of commercial interests began to make itself felt in the first half of the nineteenth century, that the many dangers of this coast were accurately charted.

Although the middle of the eighteenth century, when Murdoch Mackenzie (Senior) began to survey the Orkneys and west coast, is usually taken as the starting point of systematic charting of the Scottish coasts, some progress had been made up to that time. In Scotland, as elsewhere in the British Isles, the latter half of the seventeenth century was dominated by the production of bound volumes of charts in the form of a Sea Atlas. At the outset they were prepared by the flourishing Dutch School under Blaeu, Colom, Goos and Van Keulen. Later anglicised versions such as Seller's *Coasting Pilot* made their appearance but these were little more than a stop gap and hindered more than helped progress in charting. It is true that Greenvile Collins, with official backing, made a new survey of parts of the coast of Britain between 1681 and 1689 but his limited resources were all to apparent in the results he achieved. There were also many gaps and in Scotland only the east coast, the Orkneys and parts of the Shetlands were surveyed. At times Collins was able to call upon local assistance as, for example, while surveying around Aberdeen, a Mr Mar was responsible for mapping the coastline. Collins published his atlas in 1693 and during the next hundred years many subsequent editions were issued with little modification, although occasionally charts covering limited areas were added as a result of the labours of local surveyors interested in hydrography. For Scotland, however, no additions were made and the final edition of the atlas published in 1785 contained exactly the same charts as the first. During the period of popularity of the Sea Atlases, many local surveys were published in the form of chartlets, the author always hoping that the sale of the chart would repay the initial cost of engraving. Most of the charts were of very limited value for navigational purposes, being characterised by a relative wealth of land detail in contrast to a paucity of truly hydrographic information.

Alexander Bruce's chart of Loch Sunart and part of the Sound of Mull illustrates this point well (Fig. 1). Bruce's first aim was to draw attention to the supposed rich mineral wealth of the area and the dedication of the chart to General Wade suggests that he was hoping for the latter's support in a programme of road construction to open up the area. In the meantime, communications would have to be by sea and to this end, sailing directions for entering Loch Sunart are given

together with a list of dangers to be avoided. The 'chart' of the North Coast of Scotland issued in 1740 by Alexander Bryce is in the same style with superfluous information about features of interest on land but an absence of soundings. Bryce claims that the map is based on a geometrical survey and that it was done at the express wish of the Philosophical Society of Edinburgh. It is dedicated to the Earl of Norton and this suggests that Bryce wished to interest the Admiralty authorities. Official departments were not very responsive and it was left to the Learned Societies to initiate the small amount of marine surveying undertaken at this time. The Royal Society of London, for example, is mentioned in the dedication of the chart of the Orkney Isles, published in November 1744, by Captain Thomas Preston. Charts produced by serving officers in the Navy were rare, the authors for the most being private individuals with a general interest in mathematics and a flair

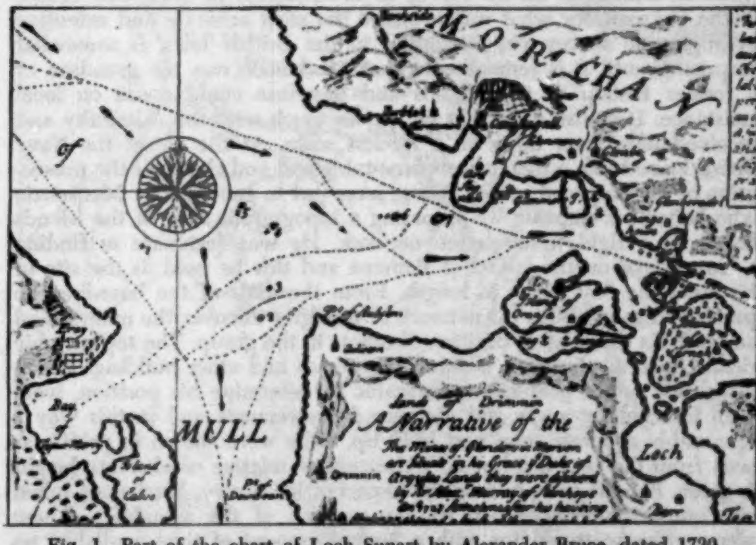

Fig. 1 Part of the chart of Loch Sunart by Alexander Bruce, dated 1730.

for practical survey. Many were drawn from the church, Bryce, for example, being a clergyman of the Established Church of Scotland. Jaffray the author of a chart of the east coast around Peterhead published in 1739 was also attached to the church while Keith, one of the first in the field with his chart of the Forth dated 1730, was attached to the Episcopal Church. Keith's chart was not entirely original for it was based, in part, on the surveys of John Adair, an enigmatic figure in Scottish hydrography. Adair was a contemporary of Greenvile Collins and while the latter was busy with his extensive surveys of the British coasts, the more thorough but lackadaisical Adair was charting the Forth, Tay and parts of the east coast. [1] Although his chart of the River Forth was engraved by Moll and published in Amsterdam in 1688, many of his other surveys lay untouched for more than a decade and

so the navigator did not immediately benefit from his labours. It was as late as 1731 before Scott published a chart of the River Clyde based on the surveys of Adair. The same time lag is apparent in another chart of the Clyde by John Watt which although based on a survey dated 1734 was not published until 1759, by which time it was completely out of date and probably erroneous in its representation of the banks and channels.

Although the individual chartlets of the private surveyors varied in accuracy, style and amount of detail shown, all had the appearance of having been hastily conceived and executed. This was not surprising in view of the lack of topographic maps, the absence of an established survey technique, the meagre resources of the individual hydrographer and the limited appeal of a chart which covered such a small area. These facts were very much in the mind of Murdoch Mackenzie (Senior) when he embarked on his survey of the Orkneys in 1744. The choice of the Orkneys, for what was to prove the most accurate and extensive hydrographic survey yet attempted in the British Isles, is somewhat surprising until it is remembered that Mackenzie was the grandson of a former Bishop of the Islands and therefore could count on local assistance. It is also clear that he was in touch with the Admiralty and received help from them on a modest scale. At the outset the Navy Board loaned him a theodolite, plane-table and and chain for the prosecution of his proposed survey. These were put to good use by Mackenzie who began his charting by preparing a topographic map of the islands based on a rigid triangulation network. He was fortunate in finding a frozen lake on the island of Pomona and this he used as the site of his base-line 3.75 miles in length. From the ends of the base-line, he proceeded to establish his network of triangles to cover the main island and also fix the relative position of others in the group. The topographic details such as churches, isolated farmsteads and other buildings which ultimately might enable the navigator to determine his position, were then inserted by angle and distance measurements and in this way a reasonably accurate map was built up. Hills were shown in profile as seen from the seaward but no indication of relative or absolute height is given. For the truly hydrographic part of his survey, Mackenzie relied on compass intersection to fix the position of the soundings. These were rather scattered for with a limited amount of time available, no extensive coverage could be attempted (Fig. 2). During the sounding operations, the type of bottom deposit was also determined by 'arming' the lead with tallow. The completed charts also gave details of tides and tidal streams, an aspect of the hydrography which particularly interested Mackenzie and led in 1751 to the presentation of a paper on the subject before the Royal Society in London. For the location of shoals and rock pinnacles, Mackenzie probably relied on local knowledge and in this connection his family association with the islands would stand him in good stead. With the completion of the survey in 1749, Mackenzie quickly had his charts engraved in London by Emmanual Bowen and in May of the following year they were published in atlas form. The superior nature of the charts compared with those previously issued for this and other areas, quickly attracted attention in maritime circles and the Admiralty was moved to back a project for

Fig. 2 A portion of Murdoch Mackenzie's survey of Orkney, published in atlas form, in May, 1750.

a survey of the whole of the west coast of Scotland, which up to that time had never been charted. With this encouragement Mackenzie lost no time in measuring a series of base lines along beaches and sands which afforded a reasonably flat surface at low water. This was followed

by a triangulation network spanning the Minch to fix the Outer Hebrides in their true relative position to the mainland. [2] Astro-sights on the sun were taken with Bird's twelve-inch quadrant for latitude determination. By 1757 the whole of the west coast as far south as the Solway Firth had been covered and nineteen sheets on a uniform scale of one inch to a mile were ultimately issued.

In style the charts were very similar to those of the earlier Orkneys survey, the relative wealth of land detail contrasting with the paucity of soundings; with one small vessel, the sloop *Culloden* and a limited amount of time, this was to be expected. For all their limitations, Mackenzie's surveys were vastly superior to those undertaken by the private surveyors in other parts. They were also based on a more advanced survey technique than contemporary topographic maps like Roy's map of the Highlands which has been described as "little more than an elaborate compass sketch". [3] Mackenzie's charts were reprinted and re-issued without amendment on a number of occasions during the next half-century. Occasionally the accuracy of the surveys was questioned, as in 1785 when a Dr Anderson writing in the *Caledonian Mercury* stated that "he was convinced that not one of them had been delineated from actual surveys but imagines they must have been sketched in by eye only and that even in a hasty and superficial manner." Admittedly towards the end of the century they had served their purpose and were in need of replacement but the strictures of Dr Anderson were unfair to a man who had spent his life in the quest of providing the mariner with charts of the difficult waters along the western seaboard.

Before the establishment of the Hydrographic Office of the Admiralty in 1795, the issue of navigational charts was largely in the hands of a few publishing firms like William Heather, Robert Sayer and John Bennett of London. It was the recognised practice, even for serving officers in the Navy, to have their surveys engraved and published privately for their own gain. The chart-publishing firms were also responsible for promoting and financing survey projects particularly of areas where the existing charts were poor and where the potential demand was high. Thus in 1776, the firm of Sayer and Bennett, commissoned Captain Joseph Huddart to carry out a survey of the St George's Channel and Irish Sea. Huddart, a Cumberland man, had had considerable experience of charting and for a time was employed by the East India Company in making a chart of the coast of Sumatra. After completing his Irish Sea survey. he was asked to proceed north to chart the west coast of Scotland, Huddart himself tell us that "the survey was carried on from observations made at Campelltawn, Tobermory, Canna and Ullapool, Laxford, Storniway, Namaddy and Bara, to determine the latitude and longitude by astronomical instruments and chronometers. From which a series of triangles determined from the true meridian was carried to find the situation of the intermediate places and remarkable objects, as a data for laying down the soundings...... I have also to remark that time would not permit me to survey the several parts of the coasts and have therefore laid them down according to the best authorities." It is clear from this

that Huddart spent most of his time fixing positions to insert a reasonably accurate graticule on this chart. Very little sounding was attempted for when the chart was published in 1781, it is clear that the soundings, names and coastline had been taken from the earlier surveys of Murdoch Mackenzie, now over a quarter of a century old. Wholesale copying without acknowledgement was common practice at that time and goes far to explain why so little real progress was made. A well-engraved chart with a fresh looking appearance would be likely to sell well even though the information from which it was compiled might be fifty years old. This was true of Huddart's chart of the west coast which went through subsequent editions in 1789, 1800 and 1811, each with only minor amendments.

Although the west coast received most attention during the latter half of the eighteenth century, the east coast was not neglected entirely. John Ainslie, who styled himself as 'a land surveyor of Edinburgh', prepared a series of manuscript charts which he forwarded to the Admiralty in 1784. The coastline and landwork is shown with great detail for the period, Ainslie being a most meticulous worker. The Admiralty, however, made no use of the surveys and when the Hydrographic Office was established, they became part of the archives of the new department. As late as 1805, Dalrymple, the first Hydrographer, was pointing out the errors in positions on the surveys and using them to draw attention to the fact that "it is a great discredit to this country that few places are determined in latitude precisely and still fewer in longitude; notwithstanding the perfection to which Instruments and Chronometers are now brought."

The hydrographic surveys which Murdo Downie made in the period 1788 to 1791 did not suffer a similar fate to those of John Ainslie. While he was stationed at Leith "finding no chart published of the east coast that could be relied upon, he took every opportunity of observing the latitude of the headlands, points and other remarkable places along the coast with their bearings from each other taken with an azimuth compass and by these means constructed a temporary chart for conducting the ships by inserting therein all the depths found from time to time." The latitudes of the various headlands was determined by astronomical observations using Hadley's quadrant. The latter instrument was also used in the land survey operations for Downie tells us that "at different times, Edinburgh Firth as far up as the Limekilns, the River Tay up to Dundee and Cromarty Harbour were each surveyed, by measuring on level ground a base line of sufficient length and taking the angles with a Hadley's quadrant which with a little practice, answers the purpose of a theodolite and by these means forming triangles, the sides of which made bases for others and by proceeding in this manner the charts were completed according to the most exact rules of surveying. The depths were next taken in a boat, either at low water or if at any other time, calculated to low water". For finding the position of the sounded depths, Downie followed the old established method of compass intersection. He was obviously unaware of the method laid down by Murdoch Mackenzie in his *Treatise on Maritim (sic) Surveying*, published in 1774 by which soundings were

fixed by sextant observations on three land objects, the resection problem being solved using the Station Pointer.[4]

After retiring from the Navy in 1789, Downie began to prepare his surveys of the Firth of Forth, Tay and Cromarty Harbour for publication. He was advised by friends to extend his surveys and to this end he charted other parts of the east coast around St Andrews and Berwick. When these surveys were completed, Downie had them engraved in London and in 1792 he issued his *New Pilot for the East Coast of Scotland.... with four charts.* In addition to his detailed charts of various parts of the coast, there was also a general chart compiled by Downie partly from his own surveys and partly from the work of others. The latter were of such poor quality, particularly with regard to the position of the major headlands, that Downie's chart is also badly out. Rattray Head, for example, was one minute out in latitude and two and a half minutes in longitude while Duncansby Head was no less than four minutes out in longitude.

With the publication of Downie's set of charts, a period of relative stagnation followed and during the next two decades, hydrographic surveys were limited to harbour plans and small stretches of coastline. In the former category are the examinations made by Graeme Spence of various harbours along the Galloway coast. Spence, although a civilian, was Head Maritime Surveyor to the Admiralty between 1788 and 1804. In this capacity he was responsible for a number of detailed surveys of various parts of the coast of south-east England as well as an accurate trigonometrical survey of the Scilly Isles. In 1793 he was sent to report on the suitablity of various harbours along the Galloway coast to act as anchorages and havens of refuge for the Kings Cutters and Revenue Cruisers. During the course of this mission he made detailed large scale surveys of the harbours of Garleston Bay, Port Yarrock, Whithorn, and Port Nessock to accompany his wordy report. Of the places examined, he preferred Garleston, largely on the grounds that the cost of harbour works there, £11,462, was less than at the other stations. At a much later date after he had retired, in 1812, Spence was asked to report on the feasiblity of "establishing a 'temporary' anchorage for a line of battleships in the harbour roadstead called Scapa Flow". Using the survey of Murdoch Mackenzie, now over sixty years old, as a base, he prepared a beautifully coloured chart on a scale of two inches to a mile which he presented with his report to their Lordships in June 1812.

Harbour surveys were also undertaken by eminent civil engineers when they were asked to report on the construction of piers and docks. Telford, for example, made a large scale survey of Port Patrick in 1809 when he was studying the possibility of its use as a packet station for Northern Ireland. Further surveys were made by John Rennie in 1815 and 1819 in connection with the building of two piers to protect what was an exposed harbour on an open coast. As late as 1846 Rennie was still interested in Port Patrick, this time in connection with the building of an inner dock and jetties to form an outer harbour.

Serving officers of the Royal Navy also made their contribution to Scottish hydrography during the period at the turn of the century before an independent Surveying Service came into being. As part of

their duties they were encouraged to keep a journal in which they noted anything of interest, both general and specific, relating to navigation. George Thompson, a Master in one of H.M.ships, was more thorough than most and his journal contained a number of hydrographic surveys and manuscript plans of harbours along the coast of south-west Scotland. His survey of the Clyde estuary, between Clough Point and Port Glasgow, in 1792 consisted of a number of sounding lines running out at right angles from the shore. No systematic coverage of the sea bed was attemped and it is obvious that the drying banks were sketched in by eye at low water. In the previous year, Thompson had made a more detailed and accurate survey of Loch Ryan on a scale of two inches to a mile. An aptitude for sketching is brought out in the journals of Lt E. H. Columbine, another regular officer in the Royal Navy. His chart of part of the Shetland Isles around Balta Sound, contains a series of fine water colours of the coast as seen from the seaward, an early example of the type of hydrographic information which was later to figure prominently in the Sailing Directions.

By the beginning of the nineteenth century a set of charts existed for the whole of the Scottish coast. Many, like those of Murdoch Mackenzie were becoming out of date and even the recently published charts of Murdo Downie were of indifferent quality, having been hurriedly conceived and too quickly executed to be otherwise. Although the Hydrographic Department was well aware of this, its own limited resources and more pressing commitments elsewhere meant that improvements in the standard of charting of the Scottish coasts were further delayed. It was not until 1815 that George Thomas, Master R. N., the successor to Graeme Spence in the post of Head Maritime Surveyor to the Admiralty, was able to make a start on the arrears. He began by surveying the Firth of Forth but in 1817 when his work was half completed, he was recalled by a counter order from the Board of Admiralty to assist Colonel Mudge, of the Ordnance Survey, in the extension of the great chain of triangles along the east coast of Scotland northwards so as to connect the Orkney and Shetland Islands to the mainland. [8]

French geodesists were also interested in the project for it would considerably increase the length of the West European Meridional Arc which at that time extended from southern Spain to northern France. M. Biot was accordingly invited to join the party sailing from Aberdeen in July, 1817. Thomas was to act as transporter of the personnel, instruments and stores and it was made clear in his orders that "it is not the wish or the intention of the Board that you are to employ yourself in making a land survey of the coast". Thomas however was interested in all branches of surveying and whether or not he kept rigidly to his orders, it is clear that he benefitted greatly from this contact with land surveyors. It is perhaps significant that no soomer had he arrived in the Shetlands than he wrote to Captain Hurd, the Hydrographer, asking for a second theodolite to be dispatched to him.

When the operations were completed in November, Thomes returned south with his vessel and for the next few seasons he was employed surveying some of the outer banks in the approaches to the Thames. It was not until October, 1822, that he was allowed to resume his survey of the Firth of Forth. By the end of the following year this was completed

and Thomas was once again recalled southwards to survey outer banks in the southern part of the North Sea. In May, 1825, however, he embarked on what was to be his major work as a hydrographic surveyor, a large scale and comprehensive survey of the Shetlands (Fig. 3). Since he was last there in 1817, the Ordnance Survey had completed the Primary triangulation of the islands but it was left in this state when all the survey officers left for Ireland in 1825. Thomas had therefore no option but to complete the triangulation and then insert sufficient land detail to facilitate fixing in the sounding operations. The time spent on the topographic survey was so great that progress in charting was extremely slow. On one occasion, the exasperated Beaufort, the Hydrographer,

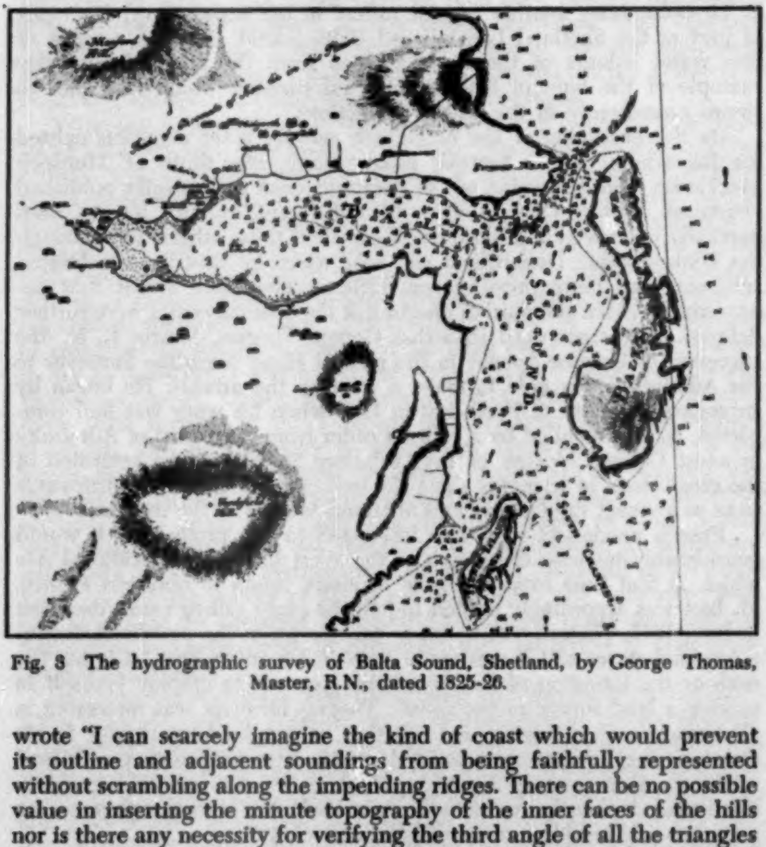

Fig. 3 The hydrographic survey of Balta Sound, Shetland, by George Thomas, Master, R.N., dated 1825-26.

wrote "I can scarcely imagine the kind of coast which would prevent its outline and adjacent soundings from being faithfully represented without scrambling along the impending ridges. There can be no possible value in inserting the minute topography of the inner faces of the hills nor is there any necessity for verifying the third angle of all the triangles in such a difficult and inaccessible country." It is true that Thomas' charts carried information relating to the archaeology, geology and mineral wealth of the country but that was only to be expected from a man with a wide range of interests. It was October 1834 before the Shetland survey was completed and Beaufort was able to write: "I have

Fig. 4 The later stages in the charting of the Scottish Coasts with dates of the surveys of various areas.

just received your letter of the 5th of September and am heartily rejoiced at the termination of the boisterous and inclement survey on which you have been so long engaged. The Orkneys are a little further south and I hope may not cost you so great a sacrifice of comfort and I fear health as the Shetlands did." After a refit at Woolwich during the winter, Thomas once more sailed north in May 1835 and apart from a break in

1841, he spent the remainder of his surveying life among the islands of the Orkney group.

While Thomas was surveying in northern latitudes, the deficiencies of the existing charts of the mainland coast were becoming more and more apparent. One of the main factors standing in the way of improvement was the absence of a topographic map on a reasonable scale. The Ordnance Survey had been pre-occupied with the six-inch survey of Ireland since 1825 with the result that Scotland was still without the one-inch map. This neglect aroused a certain amount of bitterness and in 1837 the Town Council of Edinburgh petitioned the Treasury drawing attention to this deplorable state of affairs. For certain parts of Scotland "the form and position of headlands and even considerable islands, not only on Arrowsmiths map, but in our best charts, are erroneously given and sometimes dangerous rocks are totally omitted. In some books and charts the nearest distance of the large island of Arran is stated or laid down as four miles from Bute and in others three miles from that island. Pladda Light is placed sixteen miles north of Ailsa Craig; whereas the true distance is only 10.20 miles."

For the east coast of Scotland the situation in 1837 was a little better. The Forth had been surveyed by Thomas between 1815 and 1823 and in 1830, Lt Slater began a systematic survey of the whole coast starting in the south near Berwick. By 1844 when he reached Duncansby Head and joined up with Thomas who was busily completing his survey of the Orkneys, the whole of the east coast was adequately charted for the first time. Slater had, of necessity, to establish fixed positions on land by carrying out a secondary and tertiary triangulation based on the primary triangulation of the Ordnance Survey which had lain untouched since 1821. To save time Slater restricted his land survey operations to the extreme coastal strip before sounding the offshore area using a hand lead for depth determination. The position fixing at sea was done using sextant angles on land objects, hence the necessity of a good initial land survey.

Off the west coast, accurate surveying began in 1837 after Lt Robinson had completed his examination of the shoal waters of the Solway Firth. Progress along the Galloway coast was relatively fast but once the marine surveyors entered the intricate waters of the firths and islands north of the Clyde, the area sounded during each successive surveying season became less and less. By 1864 the whole coast as far north as Cape Wrath had been covered as well as the outer islands. The north coast had also been surveyed as a continuation of the east coast survey with the result that the Scottish coastal waters were adequately charted for the first time (Fig. 4). The work of the hydrographic surveyor is never completed however, and with the introduction of more precise navigational methods, there has been a demand for even more detailed and accurate surveys based on new techniques of sounding and position fixing.

Acknowledgement: Figure 3 is based on an offical survey and is reproduced with the permission of the Controller of H.M. Stationery Office and of the Hydrographer of the Navy.

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POLLEN ANALYSIS OF PEAT DEPOSITS IN EASTERN SUTHERLAND AND CAITHNESS

S. E. Durno

THIS investigation forms another part of the long-term scheme the object of which is the study of vegetational history in Scotland by means of pollen analysis. In this instance five diagrams are described from peat deposits in the east of Sutherland and in Caithness – an area which might be described as the northern fringe of the Highlands. Two of the sites (1 and 2) are situated near the mountains of Sutherland and may be regarded as highland; two (4 and 5) are surrounded by the Caithness plain and are regarded as lowland; while the fifth (3) occupies an intermediate position. (See Figure 1).

LOCATION OF SAMPLING SITES

1. LOCH NA MOINE: Between the valleys of the rivers Helmsdale and Naver there is an extensive expanse of blanket peat at an altitude of 250-500 feet O.D. Samples were taken in a pocket of deeper peat near Loch na Moine, one of the group of lochs in the vicinity.

2. CNOC A BHROILLICH: The undulating tract of country between the Halladale and Strathy rivers is largely covered with blanket peat. Samples were taken from the deepest peat in the area, found at about 600 feet O.D., near the Cnoc a Bhroillich.

3. BRAEHOUR: Sampling was carried out on a basin of deep peat at about 250 feet O.D., on the part of Alt-na-Breac Moss next to Braehour farm. Alt-na-Breac Moss is a large area of blanket bog crossed by the railway line between the stations of Alt-na-Breac and Scotscalder.

4. FLOWS OF LEANAS: This site, in an area of deep, very wet peat much dissected by pools, lies within Achairn Moss at 300 feet O.D., a few miles to the south-west of Wick.

5. QUINTFALL: From the Moss of Quintfall samples were taken near the Black Loch at 150 feet O.D. This moss is situated at less than twelve miles from Dunnet Head, the most northerly point of the British mainland.

The following diagrams present many difficulties of interpretation e.g. the extremely low counts for oak and elm, and no attempt has been made to indicate all the zones recognised by pollen analysts. The Boreal Atlantic Transition has been indicated, but even this feature – usually so obvious in European diagrams, is not in every case well defined and the writer is aware that other workers may not agree with its position in all of the profiles.

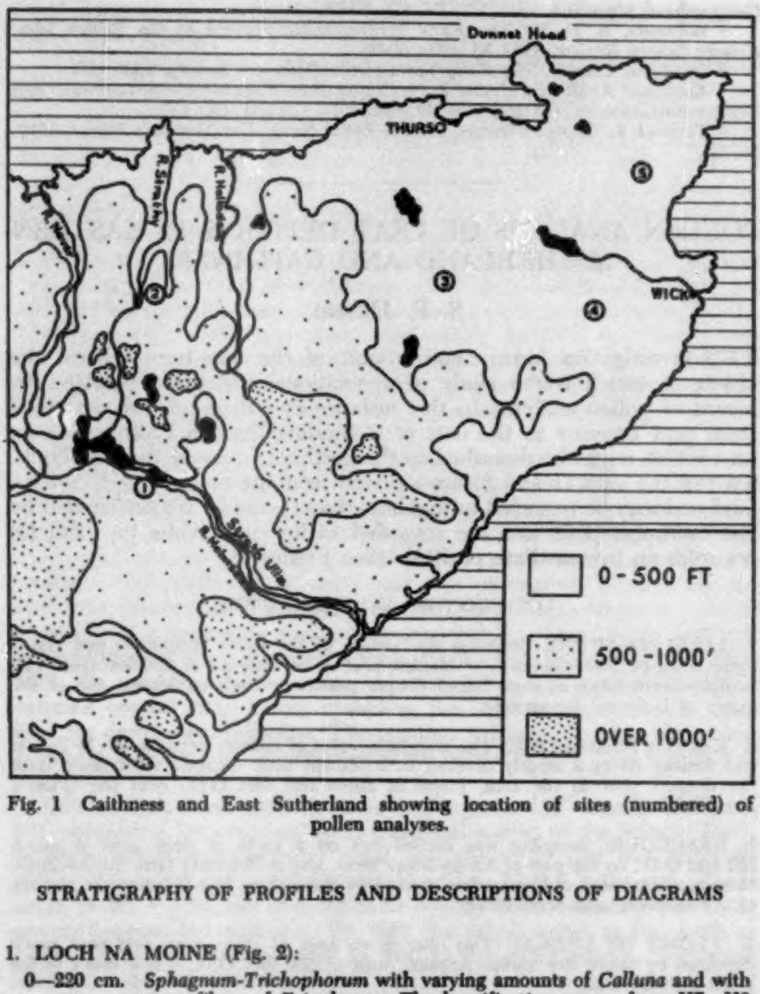

Fig. 1 Caithness and East Sutherland showing location of sites (numbered) of pollen analyses.

STRATIGRAPHY OF PROFILES AND DESCRIPTIONS OF DIAGRAMS

1. LOCH NA MOINE (Fig. 2):

0—220 cm.	*Sphagnum-Trichophorum* with varying amounts of *Calluna* and with some fibres of *Eriophorum*. The humification ranges from H7—H8 at 220 cm. to H3—H4 at the top.
220—280 cm.	Similar to the above with birch-wood.
280—470 cm.	Homogeneous sedge-grass peat; highly humified.
470—500 cm.	Diatomaceous earth.

The lower section of the profile is dominated by birch until 300 cm. This probably represents pre-Boreal and early Boreal time – Zones IV and V. At 350 cm., pine starts to rise and continues high until well into the post-Boreal period. The Boreal/Atlantic Transition is clearly seen at 220 cm., after the end of the hazel maximum where the rise of the alder commences, and where there is a stratigraphical change.

The main feature of the post-Boreal part of the diagram is the sudden end of the pine maximum at 120 cm. Following this birch is again very abundant with alder reaching its highest values. Oak and elm are both very scarce although recorded intermittently throughout the profile. The curve for the total tree percentage declines at 260 cm., due to the great increase of the Ericoid group.

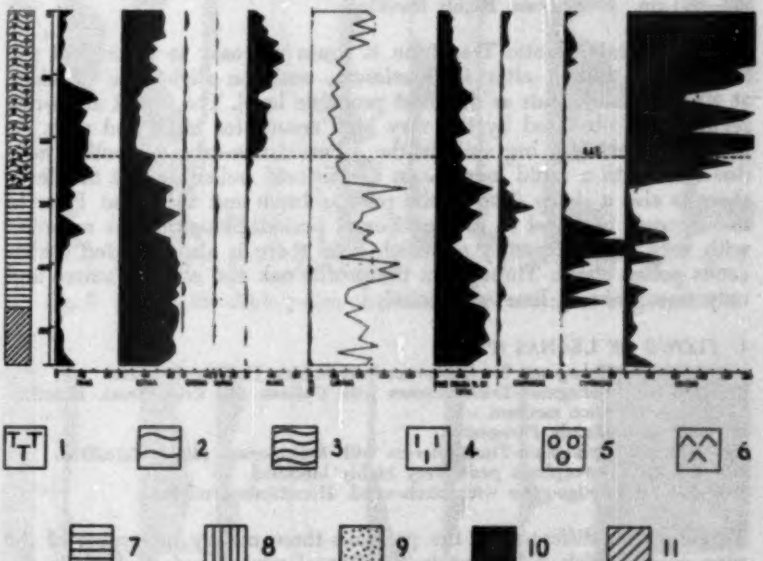

Fig. 2 Loch na Moine: pollen diagram 1. deer-grass *(Trichophorum)*; 2. bog-moss *(Sphagnum*-H. low); 3. bog-moss *(Sphagnum*-H. high); 4. cotton-grass *(Eriophorum vaginatum)*; 5. heather *(Calluna vulgaris)*; 6. wood; 7. sedge/grass; 8. reed *(Phragmites)*; 9. amorphous peat; 10. sub-soil; 11. Diatomaceous earth; B.A.T. Boreal/Atlantic Transition.

2. CNOC A BHROILLICH (Fig. 3):

0—370 cm.	*Sphagnum-Trichophorum* with some *Eriophorum* and occasional *Calluna*. Humification — lower part high, upper medium.
370—420 cm.	Sedge-grass with abundant remains of birch-wood.
420—610 cm.	Pure sedge-grass, highly humified.

The Boreal/Atlantic Transition is not clearly defined, there being no sharp rise of alder, which in fact never exceeds 25 per cent of total tree pollen. The main clues to the position of the Boreal/Atlantic Transition occur at 370 cm., where alder is rising slowly, birch falling, and a change of stratigraphy takes place. The hazel curve, which is at its maximum at 420 cm., drops to low values in the early post-Boreal period. In this period, pine together with total tree pollen curve receeds at 240 cm. The upper portion of the diagram shows birch the most abundant tree with subsidiary alder and pine. The later post-Boreal is also characterised by very high frequencies of Ericoid pollen.

3. BRAEHOUR (Fig. 4):

0—180 cm.	*Sphagnum-Trichophorum* with some *Eriophorum*. Medium humification.
180—340 cm.	*Sphagnum-Trichophorum*. Highly humified.
340—500 cm.	*Sphagnum-Trichophorum* with *Eriophorum* and *Calluna*. Well humified.
500—520 cm.	Sedge-grass. Well humified.
520—560 cm.	*Trichophorum-Eriophorum*. Well humified.
560—650 cm.	Sedge-grass. Highly humified.

The Boreal/Atlantic Transition is again not easy to place, but the hazel curve falling after its maximum, and the slight rise of alder at 400 cm., marks this as the most probable level. The initial alder rise seems to be obscured by the very high counts for birch and pine. At 280 cm., there is a big shift in the arboreal/non-arboreal pollen ratio due mainly to a rapid increase in the Ericoid pollen and at this level there is also a sharp drop in the pine as birch and alder rise. Prior to the increase of hazel in the pre-Boreal period, *Selaginella* is recorded with very high frequency at which level there is also a varied herbaceous pollen count. Throughout the profile oak and elm are scarce and only one grain of lime was noted.

4. FLOWS OF LEANAS (Fig. 5):

0—120 cm.	*Sphagnum-Trichophorum-Eriophorum*. Humification low.
120—180 cm.	*Sphagnum-Trichophorum* with *Calluna* and *Eriophorum*. Humification medium.
180—260 cm.	Mainly *Phragmites*.
260—310 cm.	*Sphagnum-Trichophorum* with *Eriophorum*. Highly humified.
310—380 cm.	Amorphous peat. Very highly humified.
380—550 cm.	Sedge-grass with birch-wood. Humification medium.

This diagram differs from the previous three mainly in respect of the pine curve which is highest in the Boreal period and declines in the post-Boreal. The Boreal/Atlantic Transition is placed at 380 cm., where the hazel is at a minimum, alder starts a rise to high values, and there is a change in the peat stratigraphy. At 360 cm., the total tree pollen falls rapidly and continues low until the top of the profile due mainly to the very high Ericoid pollen frequency. The trees of the mixed oakwood are again very scarce.

5. QUINTFALL (Fig. 6):

0—100 cm.	*Sphagnum* with *Eriophorum*, *Calluna* and *Trichophorum*. Humification low to medium.
100—150 cm.	*Sphagnum* with *Eriophorum* and *Calluna*. Humification medium to high.
150—270 cm.	Sedge-grass. Humification high.
270—350 cm.	Sedge-grass with birch-wood. *Menyanthes* seeds. Humification high.

In this diagram the Boreal/Atlantic Transition may be placed at 200 cm., the level of rising alder, low pine, and hazel increasing again after the minimum of the late Boreal; birch is at its maximum and the total tree pollen is rapidly falling away from its high Boreal values. Throughout the post-Boreal period birch dominates the arboreal count, and in the pre-Boreal pine exceeds it at only a few levels. Oak and elm are very low, ash is recorded four times, and lime only once.

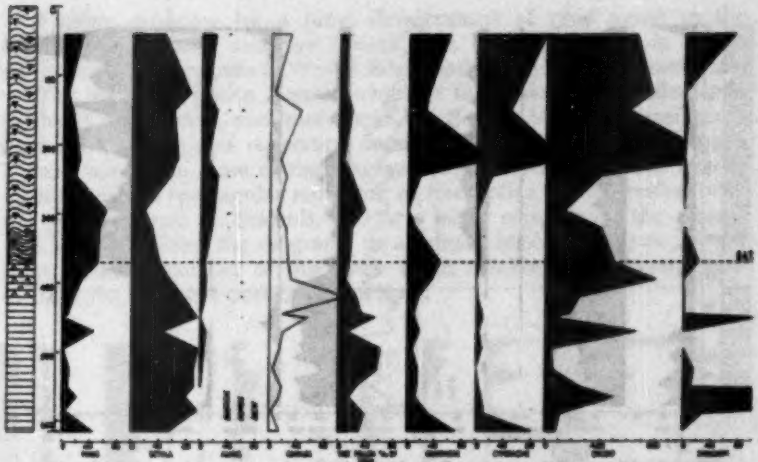

Fig. 3 Cnoc a Bhroillich: pollen diagram (for key to symbols see Fig. 2).

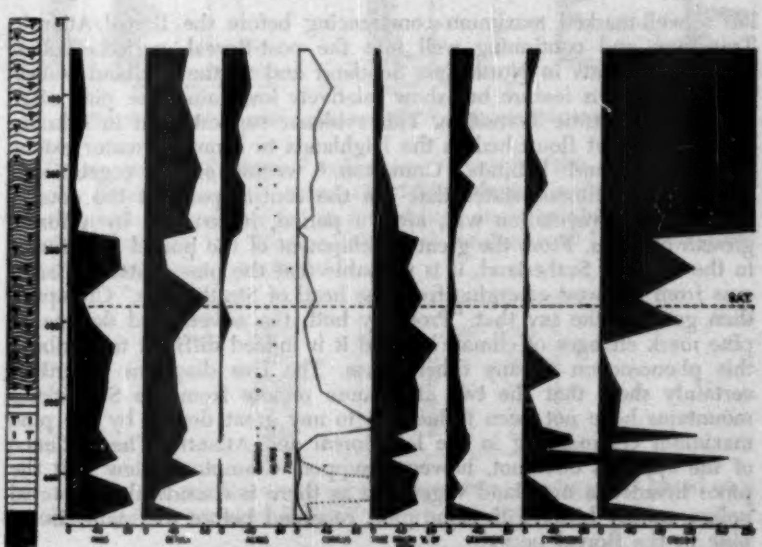

Fig. 4 Brachour: pollen diagram (for key to symbols see Fig. 2). *Selaginella* - dotted curve in *Corylus* Column.

One of the most interesting features of these diagrams is the pine curve from profiles representing sites 1, 2 and 3 (Figs. 2, 3 and 4), which show trends markedly different from those of pollen counts from sources outside the highland area. The pine curves from lowland Caithness — sites 4 and 5 (Figs. 5 and 6) — do, however, correspond more closely with those in previously published analyses from non-highland localities. [1, 2] Pine in the diagrams from the first three sites

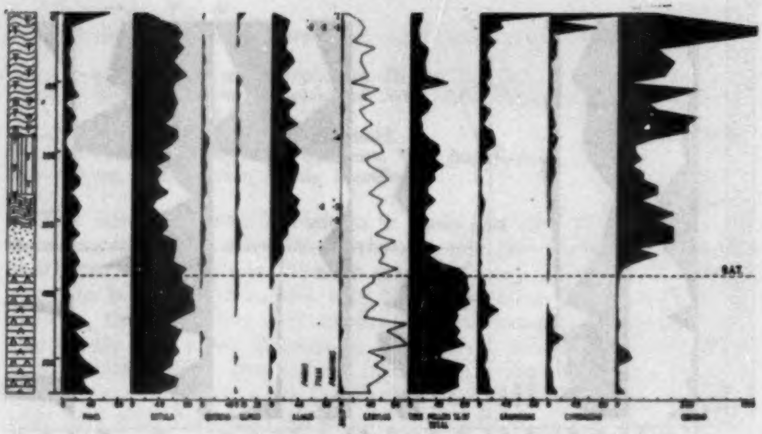

Fig. 5 Flows of Leanas: pollen diagram (for key to symbols see Fig. 2).

has a well-marked maximum commencing before the Boreal/Atlantic Transition and continuing well into the post-Boreal period. Pollen analyses of peats in North-East Scotland and in the Midland Valley do not have this feature but show relatively low values for pine after the Boreal/Atlantic Transition. This evidence suggests that in Atlantic time pine forest flourished in the Highlands to a much greater extent than in lowland habitats. Crampton,[3] writing of the vegetational history of Caithness, states that "In the central parts of the county the moorland vegetation was, after a period, interrupted by a forest growth of pines. From the great development of the buried pine forest in the heart of Sutherland, it is probable that the pines entered Caithness from the west emerging from the head of Strath Ullie." Crampton then goes on the say that "Probably both the advent and decline of pine mark changes of climate" – and it is indeed difficult to attribute this phenomenon to any other cause. The five diagrams described certainly show that the two sites more remote from the Sutherland mountains have not been influenced to any great degree by the pine maximum commencing in the late-Boreal and Atlantic. The evidence of the analyses does not, however, support Crampton's view that the pines invaded a moorland vegetation as there is considerable arboreal pollen, mostly birch with some pine, recorded before the main rise of pine in the Boreal period.

The Boreal/Atlantic Transition with its change from a climate characterised by cold winters and warm dry summers, to the Atlantic climate with increased precipitation and smaller seasonal variation in temperature, would appear to be unfavourable for pine, but in the profiles 1, 2 and 3 (Figs. 2, 3 and 4), there is little sign of an adverse effect on the pine pollen frequency which remains high until later in post-Boreal time – probably to the end of the sub-Boreal period. Several authors refer to pine in Scotland being largely resticted to the highlands after the onset of Atlantic time.[4, 5, 6]

Further evidence for a great development of pine forest in the Highlands in Boreal and post-Boreal time, has been found in pollen analyses of peat deposits in Wester Ross[7] and in the Eastern Grampians.

The total tree pollen count shows that forest was most widespread in the Boreal period, and that about the Boreal/Atlantic Transition it gave way to a type of vegetation dominated by Ericoid plants in particular *Calluna*. In some of the diagrams (*e.g.* Flows of Leanas. Fig. 5) there is quite a spectacular reduction of tree pollen corresponding with the great increase of Ericoids, and to a lesser extent with the grasses and sedges. Taking the diagrams as a whole, birch appears to be the most constant member of the entire flora, reaching high percentages in both the pre- and post-Boreal periods.

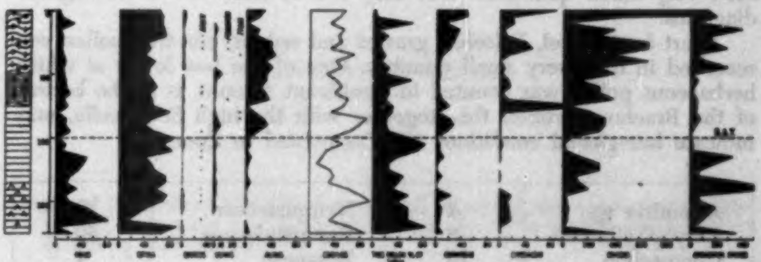

Fig. 6 Quintfall: pollen diagram (for key to symbols see Fig. 2).

In his paper, Erdtman[9] calculates values for the individual tree species based on a total count of 14,843 arboreal pollen grains from all the deposits sampled in an area which includes the whole of the north of Scotland, the Western Isles, and the Northern Isles. This gives the following pollen spectrum: —

Birch	70 per cent
Pine	14.6 „ „
Alder	11.8 „ „
Oak	2.4 „ „
Elm	1.2 „ „

A similar calculation was done in the present investigation, based on a total tree pollen count of 17,637 from all five sites: —

Birch	60 per cent	Elm	1.0 per cent
Pine	24 „ „	Lime	.08 „ „
Alder	14 „ „	Ash	.02 „ „
Oak	1 „ „	Beech	.02 „ „

The frequency of pine was also calculated for each deposit giving the following results which show pine more abundantly represented in the three highland sites than in the two lowland: —

	Sites 1, 2 and 3	Sites 4 and 5
Pine	28.3 per cent	19.0 per cent
Birch	59.6 " "	60.5 " "
Alder	10.3 " "	17.5 " "
'Others'	1.8 " "	3.0 " "

Alder is not so frequent as in diagrams from futher south, but from Atlantic time onwards it is always present and may reach co-dominance with birch, *e.g.* in the first part of the post-Boreal period in the Loch na Moine analysis. As indicated above the other tree species are present in such very small quantities that they are of little use in zoning the diagrams.

Apart from hazel, Ericoids, grasses and sedges, non-tree pollen was recorded in only very small quantity. One of the few levels at which herbaceous pollen was counted in significant amount, is at the bottom of the Braehour profile: this, together with the high *Selaginella*, may indicate late-glacial conditions such as existed in Zone IV.

Artemisia sp.	4	Nymphaeceae	2
Caryophyllaceae	8	Ranunculaceae	50
Compositae	10	Rosaceae	4
Epilobium sp.	2	Selaginella	22
Geraniaceae	6	Lycopodiaceae	8

Sample No. 66 Braehour. Herbaceous pollen etc., as a percentage of tree pollen.

The stratigraphy in all the sites is similar with sedge-grass peat (with or without wood) changing to a *Sphagnum* type (along with one or more of cotton-grass, deer-grass, or heather). The sedge-grass peat is an indication of the early soligenous development which occurred in hollows before the general growth of ombrogenous blanket peat commenced at the onset of Atlantic time and is now so widespread over much of the north and west of the country. The poorly defined stratification of the upper peat in the profiles is characteristic of blanket bog.

The author wishes to thank the following: Dr E. M. Knox, for her work on the Braehour pollen analysis; Miss M. Findlay, for pollen counting and preparing the diagrams and Mr A. Tomter, and his staff of the Department of Agriculture for Scotland Peat Division for help in obtaining samples in the field.

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REVIEWS OF BOOKS

EUROPE

Origins of Ownership: A brief history of land ownership and tenure from earliest time to the modern era. By D. R. Denham. $8^3/_4 \times 5^3/_4$. Pp.120. London: Allen & Unwin, 1958, 22s.6.d.

Mr Denham has skillfully cleared a way through the mass of —blished material bearing on this complex subject. He devotes a chapter each to Prehistory, Roman Britain, Old (Anglo-Saxon) England, the Norman period, two to the Middle Ages, and finally, one to urban (borough) property. At first the available evidence is discouragingly thin, and all along its interpretation involves great difficulty. Specialists may differ on points of detail and emphasis (assarting, for instance, surely merits fuller consideration) but geographers generally should find this a work of great value and interest. Sub-titles signpost the author's argument and make for easy reference. Some cover more or less familiar ground — eg *Earliest Settlement Patterns, First Ploughlands, Land Use in Roman Times, Saxon Open Fields and other Field Systems,* the *Vill Economy.* There is a useful bibliography at the end of each chapter, and many will welcome the direct discussion of terms *(foldland, leanland, sokeland)* often lightly dismissed in more general histories. A precise and interesting style smooths the reader's path, but the complete absence of maps and illustrations is disappointing. Aerial photographs in particular could have been used to advantage. This, however, seems the only serious blemish in a generally admirable survey. R.A.D.

Clyde Waters: Variations and Diversions on a Theme of Pleasure. By Maurice Lindsay. $8^1/_2 \times 5^1/_2$. Pp. 191. 20 illustrations. London: Robert Hale Ltd., 1958, 18s.

Holidays on the Firth of Clyde provide a theme of pleasure that was more unalloyed during the inter-war years, when the author absorbed the scene, and even more so before then. His description, largely autobiographical, of life "doon the wa'er" quite naturally involves an account of the development of the region as holiday resort. The makar's variations and diversions on the theme cover a wide range of topics, and poetry forby, but relevant to his story. The book is evocative and provides a valuable record of a pattern that "cracked and splintered" in 1939, and of a mental atmosphere both serious and blithe. The enjoyment of Maurice Lindsay's story is enhanced by reproductions of photographs and of nineteenth century prints. *J.H.K.*

ROYAL SCOTTISH GEOGRAPHICAL SOCIETY

PROCEEDINGS

MEETINGS OF COUNCIL were held on 15th April and 24th June 1958.

AWARDS: THE SCOTTISH GEOGRAPHICAL MEDAL (The Society's Gold Medal) was awared to Vivian Ernest Fuchs "For Scientific Work and Achievement on making the first crossing of the Antarctic Continent, 24th November 1957—2nd March 1958" (15th April 1958).

The medal was presented to Sir Vivian Fuchs by the President, Dr Douglas Allan, C.B.E., prior to Sir Vivian's lecture in the Usher Hall, Edinburgh, on 12th June 1958.

After the lecture a reception was held in the City Chambers by the Lord Provost and City Fathers, and was attended by a large number of members and guests.

HONORARY LIFE MEMBERSHIP AND HONORARY FELLOWSHIPS were conferred upon General Sir James Handyside Marshall-Cornwall, K.C.B., C.B.E., D.S.O., M.C., President of the Royal Geographical Society, "For his invaluable and long-sustained services to Geography". (11th February 1958).

THE DIPLOMA OF FELLOWSHIP was conferred upon Jessie Robertson Manson, M.A., "For unremitting and successful work in the Teaching of Geography in the United Kingdom and in South Africa". (15th April 1958).

OBITUARIES: It is with regret that we have to record the following deaths: Mrs K. M. K. Sharpley, a member for fifty years and a Life Member; Frank Kingdom Ward, O.B.E., awarded the Livingstone Medal in 1936 in recognition of his exploration and research work in Tibet and Upper Burma; The Rev. W. C. Galbraith, a member of Glasgow Centre Committee.

ANNUAL GENERAL MEETING

THE ANNUAL GENERAL MEETING will be held in the Society's Rooms, Edinburgh on Tuesday, 7th October 1958.

SPECIAL LECTURE

Sir Vivian Fuchs lectured on "The Trans-Antartic Expedition, 1957-58" in the *Usher Hall*, Edinburgh, 12th June 1958 and in *St Andrew's (Grand) Hall*, Glasgow, 13th June 1958.

ANNUAL SUMMER EXCURSION

This took the form of a coach trip to Fife on the 31st of May in which 82 members participated. The Society is indebted to Dr K. MacIver and Mr Patterson of the Geography Department, The University of St Andrews for arranging a tour of St Andrews University and town.

ROYAL SCOTTISH GEOGRAPHICAL SOCIETY'S TOURS

Morocco—Spain	:	May, 1958
Germany—Austria	:	June—August, 1958
Switzerland	:	August, 1958
Norway	:	July, 1958

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